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CHANGES IN SOME OF OUR CONCEPTIONS AND PRACTICES OF PERSONNEL[1]

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The term *personnel* implies a contrast relationship to material. Just as material includes all the material equipment owned or used by an institution or organization, so personnel signifies all the individuals connected with such an institution or organization. If we define applied psychology as the science and art of the control of human behavior, a large proportion of the field of applied psychology is denoted by the term personnel administration.

Those of us who are engaged directly in personnel administration in such organizations as educational institutions, the army, the navy, industry and commerce, use the term personnel administration to include securing, testing, selecting, hiring, placing, training, supervising, disciplining, stimulating, directing, transferring, discharging and promoting each individual concerned; and in developing the morale, increasing the *esprit de corps*, and creating and sustaining a contented and efficient group of individuals.

In this sense personnel administration is as old as human institutions. The practice of personnel could not be postponed awaiting an adequate theoretical foundation. Every bad personnel practice doubtless resulted from a false conception and reflects itself in strengthening rather than in weakening the error. This vicious circle is counterbalanced by the fortunate circumstance that advanced personnel prac-

[1] Address of the president, before the American Psychological Association, Cambridge Meeting, December, 1919.

tice results from true conceptions and reflects itself in strengthening and purifying the truth. Theory and practice here as elsewhere are inseparable.

Because of the importance of personnel administration, because of its complexity and difficulty, and because of the very large amount of attention given to its various phases, no profound and lasting changes in either the conceptions or the practice of personnel are brought about suddenly or by a single one of the numerous workers in this field. However, significant developments are being brought about from the combined efforts of progressive workers.

During the nineteenth century many advances were made in our conception of the material world and in our practice of dealing with its various factors. The twentieth century is characterized by an appreciation of the personnel problem, by the possession of the behavioristic point of view in psychology, and by the presence of numerous trained experts devoting their energy to the development of the concepts and practice of personnel. Constantly increasing numbers of the members of the American Psychological Association are making contributions to the field of personnel. It may be contended that no other group of experts equals the members of this Association in the number and in the importance of the contributions made—certainly to the theory, and possibly to the practice of personnel. It is too early in the century to present the various contributions with adequate prospective, and to estimate their importance. My aim at this time is to call attention to certain typical changes that have come about in our conceptions and practices of personnel and to encourage the members of this association to renewed energy in producing further changes.

The first of these changes to which attention is called is the conception of the *Equality of Men* and the practices associated with that conception. In the ancient Athenian thought emphasis was put on the superiority of the Athenians and the comparative inferiority of all other races. The associated practice is found in the enslavement of foreign races and in the custom of according equal but unrestricted

honor to all the citizens. No citizen was assumed to be superior to any other. Accordingly the casting of lots decided which one from among all the citizens was to be chosen to judge a dramatic or musical festival, to preside at court, to be a legislator, or for one day at least to hold the highest office in Athens, or to be an archon for a year and then a permanent member of the Aræopagus.

This same insistence on the equality of men was dominant in the writings of many of the great thinkers for two centuries. It found expression even in the writings of such a Royalist as Thomas Hobbes, as is indicated by the following quotation from his "Leviathan": "The question who is the better man has no place in the condition of mere nature; where, as has been shown before, all men are equal. . . .

"Nature hath made men so equal in the faculties of the body and mind, as that, though there be found one man sometimes manifestly stronger in body and quicker in mind than another, yet when all is reckoned together the difference between man and man is not so considerable as that one man can therefore claim to himself any benefit to which another may not pretend as well as he. For as to the strength of the body, the weakest has strength enough to kill the strongest. . . . As to the faculties of the mind, I find yet a greater equality amongst men than that of strength. For Prudence is but Experience; which equal time equally bestows on all men, in those things they equally apply themselves unto. That which may perhaps make such equality incredible, is but a vain conceit of one's own wisdom, which almost all men think they have in a greater degree than the Vulgar, that is, than all men but themselves, and a few others, whom by Fame, or for concurring with themselves, they approve. . . . But that proveth rather that men are in that point equal, than unequal. For there is not ordinarily a greater sign of the equal distribution of anything, than that every man is contented with his share."

It was no mere accident that Thomas Jefferson wrote into our first official document the doctrine that "All men are created equal." He was doubtless thinking primarily of men

in their political relationship, but there seems no reason to interpret his meaning as confined to political relationships. The associated practice of universal citizenship must not be thought of as an isolated phenomenon but is to be grouped with all practices arising in connection with the theory of the equality of talents, rights, and responsibilities.

The theory of the equality of men as related to education is strikingly presented in the following quotation from Adam Smith: "The difference of natural talents in different men is, in reality, much less than we are aware of; and the very different genius which appears to distinguish men of different professions, when grown up to maturity, is not upon many occasions so much the cause, as the effect of the division of labor. The difference between the most dissimilar characters, between a philosopher and a common street porter, for example, seems to arise not so much from nature, as from habit, custom, and education. When they come into the world, and for the first six or eight years of their existence, they were, perhaps, very much alike, and neither their parents or playfellows could perceive any remarkable difference. About that age, or soon after, they came to be employed in very different occupations. The difference of talents come then to be taken notice of, and widens by degrees, till at last the vanity of the philosopher is willing to acknowledge scarce any resemblance."

The conception of the efficacy of education in modifying the inherent equality of men is responsible for much of the good and much of the bad in American educational practices. Among these may be cited, on the one side, our universal compulsory education and, on the other side, the introduction into the colored schools of the South of educational practices from the classical preparatory schools of the North.

An unquestioned acceptance of the concept of the equality of men results in inefficiency wherever applied. In the army it results in seniority promotion. In labor unions it results in an insistence upon an equality of wages for all the workers of a craft. In popular thought on matters of social control it leads to communism and syndicalism. In industry it

results in the shaping of jobs to suit the capacity of the average man, with the consequent elimination of adequate stimulus to action for the superior individuals. The concept of the equality of all normal adult men is a psychological error that has perverted the thinking and weakened the action of all peoples inspired with a true and worthy ideal of democracy.

Possibly the greatest single achievement of the members of the American Psychological Association is the establishment of the psychology of individual differences. You have discovered that normal adult men differ greatly in all human capacities and attainments. You have demonstrated that such differences are much greater than had ever been imagined. You have found that individual differences are relatively small in such matters as height, weight, physical strength, and reaction-time, but that normal adults differ enormously in the so-called higher mental qualities. Guided by this new conception of individual differences you have entered the schools and insisted that pupils be grouped by their mental ages rather than by their chronological ages. You have entered the army and urged that enlisted men be assigned according to their fitness for army tasks rather than by the location of their place of enlistment. You have insisted that commissioned officers be promoted according to merit rather than by seniority. You have coöperated with progressive labor unions in developing a conception and practice adequate to provide protection for the weak and opportunity for the strong. You have entered industry and insisted that applicants be accepted according to fixed standards; that workers be promoted according to attainments and that each employee be inspired by the particular stimulus most effective for him. Your gospel of diversified talents is permeating our national thought and indicating, on the one hand, the wisdom of a democracy utilizing experts in all fields and, on the other hand, the hazard of all methods of social control based on the assumed equality of normal adults.

A second change in our conception and practice of personnel administration is seen in the decreasing importance

ascribed to *Reason* as a factor in determining human action. For many centuries man was defined as the reasoning animal. Aristotle's "Logic" was the standard textbook for all students desiring to learn the best method of influencing and controlling men. For persuasion the syllogism was believed to be the most perfect tool. Arguments to be effective must be analyzed and presented in a logical form. The hearer was supposed to criticize appeals by the most rigorous of logical standards.

The change in this point of view has come about so gradually that we fail to appreciate its extent. At the hands of certain authors the importance of reason is minimized by an emphasis upon suggestion as descriptive of the process of influencing men. Others contrast reason and instinct, urging the important part instincts play not only in the behavior of young children but also in the more important acts of adults.

Still other scientists stress the significance of sentiments and emotions, of impulse and habit, or of other forms of human response not reducible to any standard type of reasoning. This change in our concept of the importance of reasoning is observable in the writings of modern psychologists, and is reflected also in the practices of the more progressive leaders in personnel administration.

The folly of treating workers merely as reasoning animals but the wisdom of recognizing the importance of sentiment is strikingly illustrated by the following instance:

The workers in the men's clothing industry, in Chicago, were discontented last spring, because of various conditions in the industry. To reduce this discontent some of the companies increased wages 10 per cent. Company X. posted a notice that on July 1, each worker who remained loyal to the firm until June 13, would receive "a special extra pay envelope." This promise failed to change the attitude of the workers. A few weeks after the posting of this notice the drive was on for the sale of Liberty Bonds and the President of Company X. purchased $34,000 worth of the bonds as a gift to his employees. Each worker was given a coupon good for his

share of the $34,000 worth of bonds. The workers manifested no appreciation of this gift. On July 1, each worker received a special extra pay envelope containing a sum of money equal to that which he had received on the second week in May—a typical week. This generosity resulted in expression of discontent among the rank and file of the workers. The president of the company was much disappointed by the failure of his program and called into conference on the subject the local labor leader. I was asked to be present also. The following is the substance of the conversation between the president of Company X. and the labor leader.

President X: "I can't understand the lack of appreciation of my men. I gave them $34,000 worth of Liberty bonds and a special extra pay envelope of a full week's wages. The union agreement has now put all the firms on an equal wage basis. Although I did not increase wages 10 per cent. for the period preceding the union agreement I have given my men more than any other company by the extra pay envelope and the Liberty bonds. I can't see what more they want."

The Labor Leader: "Yes, Mr. X, you have done all you say and your people are not contented as the people are at the other houses. They wanted the 10 per cent. and felt that they had deserved it."

President X: "No, I did not give them the 10 per cent., but I did give the extra pay envelope and the Liberty bonds which amounted to much more than the 10 per cent."

Labor Leader: "Yes, I have figured it up and you gave them in extra pay and bonds somewhat over $10,000 more than they would have received by the increase they asked. But that is not what they wanted. They do not want the gift of the extra pay envelope and of the bonds but they do want the 10 per cent. even if it is less than the extra pay and the bonds. I believe they would be willing to refund the $34,000 worth of bonds if you would give them the $24,000 in what they regard as earned wages."

President X: "Very well, I will gladly make the exchange for I shall thereby gain $10,000.

Labor Leader: "I think the discontent will be greatly

reduced by the exchange. I will take it up with the people at once."

The proposition was presented to the workers and was accepted enthusiastically even though it entailed a recognized monetary loss of $10,000. However, it restored their offended pride and left them happy.

The President reasoned as follows:

Major premise, All wage earners prefer the greater to the lesser amount of money.

Minor premise, The extra pay and the bonds is greater than the 10 per cent. increase.

Conclusion, Therefore, the workers prefer the bonds and the extra pay.

The experienced labor leader recognized that working people are influenced as much by pride and by sentiment as by the logic of the greater gain. He knew that strikes and demands for more pay and shorter hours are frequently but a defense reaction against offended pride, and that the rational interpretation placed on such action is usually as false as the interpretation of President X upon the actions of his men. The industrial leader who seeks to comprehend and to lead his men to-day finds little assistance in Aristotle's logic or in any conception that stresses the logical reasoning ability of man. He does, however, receive great assistance from the newer emphasis on the non-rational aspects of human actions, as expounded by the members of this Association.

The third betterment in personnel administration to which attention is called is that of the change in our conception and practice of *Education*. To the popular mind education is frequently assumed to be identical with learning, with the acquisition of information more or less useful, with the committing to memory of the deeds and thoughts of forefathers more or less worthy, and with the perpetuation of the classical culture whether that be interpreted to mean Greek, Roman, Hebrew, Turkish, Chinese, or Germanic.

Education is thought of as esoteric,—as a thing quite apart from everyday life. It manifests itself as culture for

culture's sake, as art for art's sake, or as pure science uncontaminated with any possible practical results. A deep gulf is assumed to separate learning and doing, theory and practice, the school and the shop.

All these conceptions and distinctions cease to be significant as soon as we take the modern behavioristic point of view and define education as profiting by experience. Training is the result of the reactions made by the individual being trained. The laws of Solon may be 'imparted' to a phonographic record, a parrot may repeat certain phrases of the Koran and an imbecile can commit to memory the significant dates of Roman history. These instances are not descriptive of education as we think of it today because they are not instances in any real sense of profiting by experience.

In playing with fire the child secures training which in the fullest sense is education. He learns to set up a series of withdrawal reactions and to profit thereby in his increased ability to establish this particular form of reaction when facing similar situations.

The youth receives training in solving a mathematical problem if in solving it he has acquired a new way of analyzing a mathematical situation and can make use of it when such situations arise again. He receives training in the reading of Homer if in the study he acquires a new form of reaction and is enabled to profit by this new possibility of action whether it be in additional reading, in appreciating literary style in another author, in improved diction on his own part, or in comprehending human action.

The mechanic at the bench may be receiving an education if he is profiting by his experience. In solving a mechanical difficulty he may be acquiring a new form of thought that may be repeated more readily when a similar situation is met again. As a member of a group of workers he may acquire a form of social response that may appear more readily and be more effective with each repetition. As a member of a shop committee his contact with the employer's representative may change his entire point of view on industrial, social, and political philosophy. In dealing with subordinates he may

accidently or thoughtfully acquire a type of reaction that fits him for more important executive duties. The reading of a magazine article, the action of an associate, the chance juxtaposition of two pieces of material may cause him to think a new thought or perform a new act which may better equip him to meet new and important duties. The significant thing about these new reactions is that they are new and can be repeated with benefit.

According to this conception there is no rigid demarcation between school and society, between the pupil's desk and the employee's bench or counter. In all these instances the individual has experiences. Whether such experiences should be classed as education or not depends less on the particular geographical location than on the response resulting from the experience.

When education is defined as profiting by experience, the personnel director is faced with the double responsibility, first, of providing educative experience, and second, of assisting the individual to obtain the maximum of profit from the experiences provided. The worker in repetitive manufacturing processes may not be provided with adequate educative experiences and the student in college may not be profiting sufficiently by his experiences no matter how rich they be in potentialities.

Our educators in institutions of learning are aware that richness of content does not guarantee educative response on the part of the student, so adequate responses are sought as an essential part of all courses of instruction. In business organizations need for varied experiences for each individual is beginning to be recognized. Steps are being taken to provide this variety by teaching the worker not merely one job but by teaching him many jobs or by providing richness of content in other ways.

In planning his training program the personnel director is coming to see that his responsibility is not met by providing formal classroom continuation school instruction for the youths who are ambitious or for others compelled by law to take such instruction. His is a greater responsibility and

ideally demands that he should supply each employee with richness of experience and provide also that each worker should profit continuously by his experiences as an individual worker, as a member of the entire body of employees, as a prospective junior executive, as a member of a family, and as a citizen of the state.

A fourth change to which attention should be called is that of the emphasis of the *Biological Relationship* existing between the worker and his work. For a long time we have used the evolutionary-biological point of view in interpreting the relationship of man and the world in which he lives. We have gradually ceased to think of man and his environment as two contrasted and more or less independent entities. We no longer think of him as the result of a special creation coming into his world and subduing it. On the contrary, we think of man as a result of an evolutionary process in which man and the world were mutually involved. The general biological point of view is stressed in anthropology and sociology but rarely in attempts to interpret the industrial worker. This very necessary point in evaluating the concepts and practices of personnel administration is clearly expressed in extracts from an unpublished report of the Scott Company Laboratory on 'A Point of View in Industrial Personnel.'

"In order to attain an insight at all adequate into the field of industrial personnel, we must abandon any statement which contrasts, or which even sets off against one another, men and jobs. On the contrary, we must see clearly that the industrial situation, the productive complex, is organically not two things, but one; not men and over against them jobs, but in reality *workers-in-their-work*. In this active, shifting unity, this intangible, ever-changing reality, the vital problems of industrial adjustment exist.

"There is a basic difference between this concept and the older point of view toward personnel. The latter notion is perhaps most crudely stated as 'Putting square pegs into square holes.' For the sake of brevity and concreteness, let us call this the 'square peg' concept. Clearly, there is a family resemblance between the square peg concept and the

statement that personnel work consists of man-analysis, job-analysis and the bringing of man and job together. Man-analysis is essentially discovering the shape of the peg; job-analysis is essentially discovering the shape of the hole. The phrase *The Right Man in the Right Place* is the slogan of a personnel philosophy of the square peg variety.

"The inadequacy of the square peg concept arises from its sharp discrimination between man and job—man on the one side, job on the other side, with an act of bringing man and job together. Here we have drawn for us two separate entities, static, self-sufficient; our task seems to be to make as good fits as possible. The coldness, the rigidity, the sterility of this point of view is evident; it is not surprising that it results so frequently in a mechanically impersonal, jigsaw-puzzle attitude toward the problems of industrial personnel. To fit the right man in the right place, to put the square peg in the square hole, these are relatively fruitless concepts for meeting the plastic, living problems of industrial adjustment. . . .

"Our point of view differs from the square peg concept in that it shows the worker-in-his-work as a unity, a developing, living situation, as a productive complex, organically one. We do not think of the hiring of the worker as the connecting of a man with a job; it is the creation of a worker-in-his-work situation, the birth of a new productive complex. We do not think of the release of a worker as the separating of a man from his job; it is the destruction of a worker-in-his-work situation, the death of a productive complex. Square peg philosophy regards as fundamental, structural diversity, the man and the job, the worker and the work. Our point of view regards as fundamental, functional unity, the man-in-his-job, the worker-in-his-work. . . .

"The problems of industrial adjustment are conceived to be not so much those of fitting together worker and work, but rather those of securing the healthy development of an organic unity, the worker-in-his-work. The worker-in-his work is viewed as a living and changing situation, as the functional element of the great industrial and social organism, plastic and unstable. . . .

"Personnel work involves the shaping of the growth of this productive complex in forms of greatest economic effectiveness and ultimate social value."

As a final point attention is called to the change that is being brought about in our conceptions and practice of *Vocational Guidance*. The caste system of India, and allied systems in other lands, the European guilds of the middle-ages, inheritance, opportunities for jobs available in the vicinity, social approval and disapproval of certain occupations—these are among the factors that have been dominant in vocational guidance. Such general, non-commercial, and unadvertisable systems have been unable to retain a monopoly on vocational guidance. There have sprung up special systems, proporting to be infallible, in the guidance or the selection of individuals. These systems have had great vogue in all ages and today many of them are being sold to the so-called hard-headed business men in every city in America. In the list of such so-called "infallible systems" are included the following: astrology, augury, chance as manifested in drawing of straws, casting of lots or the flipping of a coin, chirography, chiromancy, clairvoyance, character analysis, divination, fortune-telling, horoscopes, hypnotism, intuition, magic, mediums, mind reading, necromancy, omens, occultism, oracles, palmistry, phrenology, physiognomy, premonitions, psychological tests, soothsaying, sorcery, sortilege, subconscious hunches, stigmata, talismans, trade tests and telepathy. When none of the systems here cited have been depended on we commonly resort to the judgment of the maiden school teacher, of the indulgent mother, of the ambitious father, of the mercenary employment agent, of the hustling labor scout, or of the listless recruiting officer. Vocational guidance has been on an utterly unscientific basis and has been wholly inadequate. However, no great improvement could be expected until a comprehensive job analysis of available vocations had been made, until a technique of testing individuals had been provided by experimental psychology and until the point of view of the biological unity of the worker-in-his-work had been recognized. During the past few years fairly

adequate job analyses have been made of most positions in many of our industrial and commercial organizations. Year by year progress is being made by our laboratories in measuring the talents, capacities, and skill of individuals. Great advance has been made in our understanding of human nature and in the creating of a practical biological point of view of the worker-in-his-work. The advance in vocational guidance may be adequately symbolized by the change from the stage in which dependence was placed on the casting of lots to the stage in which dependence is placed on the tonoscope and similar instruments of precision; or from the stage in which results were expressed in the ambiguous mutterings of mediums to the stage in which results are expressed by coefficients of correlation and by regression coefficients or by other exact statistical formulations.

Of the changes in our conceptions and practices of personnel administration mention has been made of five that are more or less typical of the many that might be cited. The importance of these changes is very great, both for the development of the science of psychology and for the welfare of the human race. It has been estimated that during the nineteenth century the power of the human race to produce food, clothing and shelter was doubled by the application of increased knowledge of the material elements of the universe. All the significant advances in knowledge of the material world were brought about by possibly a few thousand progressive minds devoted to that study.

It is quite probable that the productive power of the human race is being doubled again during the present century. The benefits of this advance will be divided between better adjustments of the material world to the needs of man, and the better adjustments of man to man. Such an increase in the efficiency of the race will probably be due to the advance in our knowledge of personnel rather than to further increase in our knowledge of the material universe. If a few thousand men in their study of the material world served their science and the race so effectively, those of us who are engaged in the study of personnel may get a glimpse of the responsibility and the opportunity that is ours.

AN ANALYSIS OF EFFORT

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The concept of will as outlined by the early faculty psychologists has been discarded, and rightly so, by modern genetic psychology. The will as a spiritual entity which served to redirect, supply and control energy for the different responses of an organism not only failed to explain many of the phenomena which gave rise to the formulation of the will concept, but in addition lent an air of mystery which in itself inhibited the scientific investigation of the processes it purported to explain.

The concept of dynamogenesis, which took the place of the will concept, assumes that a sensorial stimulus not only tends to find a direct response of some special sort but affects more or less remotely other parts of the organism. This diffusion of energy from an incoming impulse depends upon the condition of the organism as determined by its entire past history, upon other stimuli acting at the same time, as well as upon the nature of the stimulus itself. Psychologically the previous stimuli and experiences of the organism may be considered as setting the organism in a certain state of readiness or unreadiness. The task (Aufgabe) —the set of the organism, or the directions received—facilitates one reaction and inhibits another. The directions to add two numbers facilitate the adding of the numbers and inhibit any tendency to multiply or subtract. If a man has been placed in an attitude of anger this state of his organism will cause him to become highly irritated by a relatively mild stimulus. Such a simple reflex as the knee jerk is affected by other stimuli acting at the same time, such as martial music, the cry of an infant or other significant noises.[1]

[1] Lombard, W. P., 'The Variations of the Normal Knee-jerk and their Relations to the Activity of the Central Nervous System,' *Amer. J. of Psych.*, 1887, 1, 5–71.

Finally, a single stimulus if pleasant will cause a different reaction from a single unpleasant stimulus. One may smack his lips over a bit of candy but his whole organism may respond in an effort to eject some disgusting bite.

By very carefully marshalling the facts of stimulus and response, psychology has been able to explain most of human behavior by a direct relation of each response to some stimulus more or less remote. Some difficulties have arisen in connection with stimuli which elicited no immediate observable response and with responses for which there were no immediately preceding adequate stimuli. Many of the seeming difficulties disappear when the human organism is regarded as an integrating mechanism, and the working concept of modern psychology is no doubt the concept that every organism is a highly balanced system of forces, whose integrity depends upon the maintenance of a certain balance. Each stimulus is received into this system and is modified by the condition of the balance at that time and its response can only be interpreted in the light of its relation to all its previous experiences as well as to all the other forces acting upon it at that time.

Now, the question at the crux of this whole situation is, what is this tendency to maintain a balance? The term used in the will psychology to express this fact was effort. The individual was presumed to make an effort to maintain his 'personality.' If a hostile stimulus was received he made an effort to overcome it. The moral crisis was the place where this manifestation appeared in its supreme state. It is the sort of conflict which James describes in his classic fifth type of decision.[1] Why is it that "when a dreadful object is presented, or when life as a whole turns up its dark abysses to our view, the worthless ones among us lose their hold on the situation altogether . . . and collapse into yielding masses of plaintiveness and fear"; while the 'heroic mind' holds itself erect, faces the situation, and 'makes himself one of the masters and lords of life'? This question is still present even when the situation is restated in behavioristic terms,

[1] 'Principles of Psychology,' 1899, II., 534–535.

but it is simplified if one recognizes that such a question resolves itself into a query as to why individuals differ in their capacity to maintain their balance. We should expect the trait to vary; what we wish to know is: What is this trait? What is effort? What is meant by maintaining one's balance?

This paper is an attempt to show that *the concept of effort is an elementary principle of all organic life which is as fundamental as the most firmly established reflex.* To do this we will first indicate where effort is best seen, we will show facts which indicate its elementary nature and finally try to describe how the more complex situations in which effort is revealed are developments from this elementary background.

The customary definition of effort is: 'the result or display of consciously directed power.' This definition is itself a product of will psychology and in order to get away from the implications connected with the phrase 'consciously directed' we will have to change our definition to read 'the result or display of organic power.' This is not doing violence to the term. The central idea is the display of power; organic has been used in place of consciously directed. Power may result in either of two situations. (1) When a stimulus is received whose natural response would cause a loss of balance, the stimulus does not give rise to its normal reaction. Either 'power' is exerted by the other forces to divert the stimulus to an unusual response, or it is merely inhibited. (2) In the second case the organism may need to make a certain response in order to maintain its balance. Any opposition to this response will be opposed. The combined forces of the organism will tend to break down this resistance. It is effort in these two senses and not with its will implications which we will attempt to analyze.

Manifestations of Effort

Effort may be seen when an organism is learning to react to a novel situation. When an organism encounters a situation, the situation is in itself a stimulus to activity. If the activity produces a favorable impression the organism con-

tinues to respond in the same manner to that situation. If the result is not satisfactory a new reaction is tried. This may be considered an effort to meet this situation—it is the first stage of effort—the connection between stimulus and response is simple and direct; but the effort we mean to analyze is a more complex affair. Suppose the organism is placed in a new situation and makes the traditional random movements in reacting to this situation. If all the movements fail the organism could do one of two things; it could stop its activity and go to sleep or it could increase the violence of its responses to the point where it would be frantic in its struggles. The increase in power displayed in the activity of the organism when its responses fail to solve the situation is what we mean by effort. The situation is the stimulus to random movements; the *situation plus the failure* of the random movements *is the stimulus to effort* or the display of power. The failure is the added resistance in the situation and the effort is the reaction of the organism to meet the resistance.

As a specific example, suppose a dog tried to gain entrance to this room. He could come to the door and make several reactions to the fact that it is closed. He could whine, scratch, push at the crack with his nose and bark. After failing to gain access he could either go lie down or could increase the violence of his efforts until the whole neighborhood becomes disturbed by the intensity of his howling. In this sense effort is a direct response to a stimulus and the stimulus is the amount of resistance that the organism encounters.

Effort may be the response to a specific condition of the organism, such as fatigue, sickness, etc., which renders it difficult for it to make the normal response. An illustration of this rôle of effort is seen in the case of an athletic contest. The athlete starts the foot race as a response to the presence of the crowd and his competitors. Gradually fatigue sets in and the stimuli of his associates and the crowd weaken until he is impelled to stop. He feels as though he would die if he goes any further. He has no stimulus within or without

to keep up this useless running but he keeps up impelled by nothing but the stimulus of the opposition his organism is receiving and the habits he has formed of persisting in spite of opposition.

In many different psychological analyses the phenomenon of effort is given a prominent place. In discussing the effects of practice the statement is made by investigators that effort must be directed toward improvement: that, if effort is directed toward increase in accuracy, an increase in accuracy will appear; if effort is directed toward an increase in speed, an increase in speed will appear; or, if effort is directed toward improvement in both speed and accuracy, both speed and accuracy will be improved. Investigators of memory make the statement that the learner must direct his efforts toward memorizing in order to make the memorizing effective. All discussions of attention point out two kinds of attention; involuntary and voluntary. Voluntary attention requires effort on the part of the individual. Successful reasoning is conditioned upon the reasoner holding the problem to be solved against irrelevant suggestions and distractions. This process requires the direction of effort against stimuli which are unfavorable for a proper solution.

Finally, effort is seen in the moral conflicts of the individual. The instincts or the acquired complexes of the individual tend to make him react in some particular way to specific situations. Society says he cannot act in this way without receiving punishment therefor. If the threatened social punishment is able to exert force enough the tendency to act may be inhibited; there may be a balancing of forces with no apparent activity. James describes a case in which social pressure is not sufficient to inhibit activity, where the individual feels that he either will not be caught or that he will be excused in case he is caught. He has nothing to lose by refraining from an act except his moral integrity, and even this loses its restraining potency. The individual feels that by his own wilful act he is making the decision. This is an illustration of the conflict of stimuli and must be carefully distinguished from the opposition to response. Where there

is opposition to the normal response it was stated that the situation plus failure in response is the stimulus to effort. Here we have a balance between impulses neither of which can gain the ascendancy. When a decision is made it is usually with a violent impulse and not the slow response which is typical of a nearly balanced physical movement. The decision means the total inhibition of one or the other stimuli. It is evidence that *the balance*, the withholding of response, *is itself the stimulus for the organism to do something.* This stimulus arising from the conflict throws itself finally on one side or the other and a response occurs.

The Elementary Nature of Effort

Suppose that all the organisms in a group reacted in exactly the same way to the same stimulus, in other words suppose that there were no such thing as biological variation. In such a case it would be only through accident that organisms could ever become selective in their reactions. Suppose, however, that within a group two organisms responded just a little differently to the same stimulus. If this stimulus was favorable to the integrity of the organism the one which gave the most ready or the strongest response would tend to preserve its integrity better than the other. Suppose, again, that the stimulus was light and that light was very favorable for the organism in question. Those organisms which responded favorably and most vigorously to a light stimulus would have a better chance to survive than the ones which were indifferent to light. Such selection would eventually give rise to a species which would tend always to respond positively to light. (Positively phototropic). We might say that the organism 'tries' to stay in the light, that it 'exerts' itself in an 'effort 'to keep where it is light, but it can readily be seen that this is but a crude way of stating that through biological variation and selection a positively phototropic species has been evolved.

Again, suppose that from seeds which tended to throw out sprouts indiscriminately a variation arose through which some seeds tended to send sprouts toward moisture. If

moisture was favorable to the integrity of the life of the seed the ones which showed the strongest tendency would survive those in which the tendency was lacking. It can easily be seen how through a long period of selection a species could be evolved which would force its roots into the crevices of rocks, even raising tons of weight to do so.

These principles of variation and selection form the groundwork for the development of any biological trait no matter how complex. The question is, can effort be explained as a biological development of this sort? If we can show that effort is a fundamental trait of organic matter at different levels, we believe that biological selection will account for its presence. Biological evolution has been so elaborately expounded in the literature and is so widely accepted that we scarcely need to defend it. All we need to do is to show that effort is a definite response to a certain condition and biological evolution will explain its existence.

1. Jennings[1] has shown that the behavior of lower organisms depends not only on the external stimulus but on what he calls the physiological state of the organism. Physiological states are of two kinds, those depending on the progress of the metabolic processes of the organism, and those otherwise determined. The latter are the ones which concern us. The 'physiological state' is a dynamic condition and not a static affair; it tends to produce movement. "This movement often results in such a change of conditions as destroys the physiological state under consideration. But in case it does not, then the second tendency of the physiological state shows itself. It tends to resolve itself into another and different state. Condition 1 passes to condition 2, and this again to condition 3. This tendency shows itself even when the external conditions remain uniform." For example the stentor[2] is capable of greatly different reactions under the same external stimulation. If the stentor is subjected to a stimulus which would not be injurious unless applied for a long time, if the stimulus and other external conditions remain the same the organism will respond by a series of reactions

[1] 'Behavior of the Lower Organisms,' Columbia University Press, 1906, 282–299.
[2] *Ibid.*, p. 176.

becoming more and more pronounced in character, until by one of them it rids itself of the stimulation. The changes in behavior may be summed up as follows:

"1. No reaction at first: the organism continues its normal activities for a short time.

"2. Then a slight reaction by turning into a new position —a seeming attempt to keep up the normal activities and yet get rid of the stimulation.

"3. If this is unsuccessful, we have next a slight interruption of the normal activities, in a momentary reversal of the ciliary current, tending to get rid of the source of stimulation.

"4. If the stimulus still persists, the animal breaks off its normal activity completely by contracting strongly—devoting itself entirely, as it were, to getting rid of the stimulation, though retaining the possibility of resuming its normal activity in the same place at any moment.

"5. Finally, if all these reactions remain ineffective, the animal not only gives up completely its usual activities, but puts in operation another set, having a much more radical effect in separating the animal from the stimulating agent. It abandons its tube, swims away, and forms another one in a situation where the stimulus does not act upon it."

This situation can be clearly translated into the terms of our thesis. The external stimulus was the cause of the reacting movement; the same external stimulus plus the fact that the movement was not effective in the removal of the stimulus formed the stimulus for a different movement until finally the organism made a very pronounced reaction, involving its whole body, to a stimulus which at first caused no noticeable response. While the variation in reaction at the different stages is important for psychology we are primarily concerned with the fact that there is an increasing intensity in the responses until the stimulus is removed.

2. A simple illustration will show that the same thing is present in animals of a higher order. A child upon being rebuked for pulling the cat's tail replied that he 'was simply holding and the cat was doing the pulling.' A stimulus upon the cat's tail which at first will cause only a slight reaction

will if that slight reaction fails to remove the stimulus give place to the most violent reactions.

3. At birth a child shows the same reaction. Nothing will arouse an infant to struggles and cries of seeming rage as quickly as holding its arms close to its sides so that it cannot move them. The child will resist movements of parts of its organism and will increase the intensity of its resistance if its first movements do not serve to remove the undesirable stimulus.

4. A living muscle adapts itself in its contraction to the resistance it meets. This fact has been known for some time to physiologists. Luciani says;[1] "According to the observations originally made by Fick, and afterwards confirmed by others, when the weight applied to the muscle is not great, and particularly when an elastic resistance is opposed to the muscle, so that its tension increases constantly during contraction, the shortening is greater when the weight and the initial resistance are increased. This paradoxical phenomenon is a specific property of the substance of living muscle, and shows that the sudden pull of the muscle and increase of tension during shortening act as a stimulus on the contractile substance, and increase the effect of the electrical stimulation."

5. It has been found in experiments with human subjects that the force used in pulling a weight is determined by the magnitude of the load.[2] "After one has been pulling a weight of 2,440 grams with what he supposes to be the maximum force he is able to exert, when unexpectedly a weight of 7,770 grams is substituted for the lighter one, his force at the very beginning of the pull is on the average 2.5 times as great as the supposedly maximum force previously used." The time taken for this adjustment ranges from 25 sigma to 91 sigma with an average of 54 sigma. This is much shorter than the simple reaction time, which under the most favorable circumstances can scarcely be reduced to 100 sigma. Since

[1] 'Human Physiology,' Trans. by F. A. Welby, Macmillan, Vol. III, pp. 13, 15, and 46. See also 'The Speed and Accuracy of Motor Adjustments,' by the writer of this paper, *Jour. of Exper. Psychol.*, 1917, 2, 225, 248.

[2] Morgan, J. J. B., 'The Overcoming of Distraction and Other Resistances,' *Archives of Psychol.*, 1916, No. 35, Chap. VII.

this adjustment is so rapid it cannot be a conscious reaction. It must be a reflex or a local muscular adjustment. In either case the adjustment is certainly elementary.

6. In experiments on the distraction of attention it has been found that individuals oppose distractions with increased effort as well as by introducing other factors into their work which will help them to overcome the distractions. These adjustments are not made consciously but reflexly; the subjects often asserting that they do not use the help that their reactions indicate. For instance a customary reaction was to articulate the material used in the process involved. Breathing records were taken which indicated articulation and the subjects were watched through a peep hole. Some subjects who actually moved their lips in articulating denied that they had made any such movements. In such a process as overcoming distractions the exertion of effort is unconscious.[1]

We have seen that the force exerted by an organism is a direct response to resistance encountered. This adjustment is seen in an organism as elementary as the stentor, in higher animals, in infants at birth, in a nerve muscle preparation, in muscle intact in the organism, and finally in complex human activities such as resisting distraction. Using the definition of effort given above we can say that *effort is an immediate response to the stimulus of failure.* Failure is used to mean the persistence of an unsatisfying situation in spite of the normal reaction to that situation.

Let us now see whether complex types of mental effort can be analyzed as derivatives of this elementary adjustment.

Effort in Practice

Let us take first the case of the effort involved in long continued practice. In periods where no improvement is made and a plateau appears in the learning curve, the ordinary incentives fall off and subjects feel tempted to stop. In fact many learners do stop at such points and those who persist do so by what they call sheer will power. In this case no

[1] *Ibid.*, Chaps. I–VI.

resistance is added but the customary drive to activity disappears. When the man starts he sets before himself the goal of becoming proficient in the line of work in which he is practicing. His rapid progress at first enthuses him and stimulates him to work for greater improvement. When improvement comes to a standstill doubts assail him as to the possibility of his ever becoming proficient. His goal seems to fade away and he has no motive to continue except stubborn persistence.

Now if an individual did not have the power of continuing work in the face of obstacles all work would stop at such times. The only way in which we could train ourselves to work would be to learn which incentives are efficacious and how to keep them before us. We all need incentives to start us on a task and we need incentives to tide us over hard places; but as we grow older we should need fewer and fewer incentives, we should have developed this primitive trait of resisting opposition to the point where we can surmount an obstacle without any outside aid.

The ability to surmount obstacles is developed in some such way as this. A young child innately opposes any restraint upon its body or any forced movement of its members. It wants to be free to move without restraint and nothing will arouse a fighting, struggling reaction as quickly as pressing its arms to its sides and holding them there. As it gets older and wants something it will resist any interference in the way of its obtaining the thing it wants. The wise parent or teacher will not fight back when the child struggles for something, but if it should not have the desired article will substitute something else for it, thus reinforcing and redirecting rather than inhibiting the tendency to resist interference. Such training strengthens the capacity of the child to oppose force against resistance. Finally the child comes to the point where it should learn some uninteresting subject. Here the teacher presents proper incentives, attaches derived interests to the work and thus induces the child to pursue the subject. The time will come when the interests will fall off and the child will want to stop. The

teacher will add other incentives, give the child a helping hand over the hard place and in so far has trained him to oppose force against resistance. If help is not given at the proper time the child may give up and in doing so has trained himself to submit rather than resist.

It may be thought that the teacher in giving the extra incentives is simply helping the child to form a habit which will enable him to do this particular task. This is not the case. The child's whole growth is a struggle between the tendency to continue a thing once started and the opposition of outer circumstances against continuance. In ordinary cases the tendency to increase effort with an increase in opposition wins the day; but when the opposition becomes too great and the child is about to give in, this is the time the teacher should give the help. Too much help will leave this tendency in a dwarfed state, too little will train it to retreat at the slightest opposition.

Viewed in this light punishment is not as beneficial a factor in training as rewards. Punishment inhibits a certain response and hence works against the tendency to carry through a thing once started. Rewards are a reinforcement to the tendency to carry through a thing regardless of opposition. Punishment if given at all should be coupled with positive direction. Not only should an act in a specific direction be inhibited but at the same time a substitute should be provided and the offender encouraged in this alternate act.

As the child grows up under such training he is learning to persist in certain types of activity and to give up in other lines. He has learned that if he persists he can overcome resistances and come off victorious. What is there in persistency in practice more than this? If there were not an original tendency to persist upon which the teacher can build such training would be impossible; with such a tendency and proper training nothing else is needed. No mysterious exercise of a subtle faculty of effort is needed to explain such persistent practice on the part of the learner any more than it is necessary to say that when the child opposes restriction of its limbs it is consciously saying, "I will not have this man

holding my hands, I will exercise my will power and show him I will not be thus dominated." An adult makes such statements and thinks he is using a special gift of will power when he does so. If he acts on his resolution he does so because he has been schooled in using effort against resistance. If he has not so schooled himself his asseverations will be as idle as for a novice at typewriting to say, "I *will* use this machine." He can use it if the resolution marks the beginning of long practice; and a novice at mastering situations can become master if his resolution marks the beginning of practice in so doing. In both cases practice must begin with simple problems. We are all familiar with the 'jack of all trades,' the fellow who has never learned to persist in any one trade long enough to become master of it. Such a man's greatest lack lies not in the fact that he has not mastered a trade but that he has never schooled himself in the meeting of obstacles by persistence in some one trade. He has started a dozen and continued until he struck a 'snag' and then stopped.

Effort in Attention

Spontaneous attention is based upon the reflex response of an individual to an adequate stimulus. If the stimulus causes a response without involving conscious control it is a simple reflex, if the individual is vividly conscious of the response we say that he attends to it. If the first response is followed by successive responses to other details of the same object we have continued involuntary attention. An object which is able to cause a series of responses to its different details is said to be interesting to the individual. Attention to such objects involves no effort, it is a native response. It is necessary in order for one to get a proper course of training to fit him for modern social life to attend to a number of things which are not naturally interesting, to objects to which he would not naturally attend. One does this at first by attaching some outside interest to the object. The drive from this outside interest makes us attend to otherwise uninteresting objects and we still are exerting no effort to do so. At times, however, the derived interests

lose their potency, objects assail our senses which have more interest for us than the objects to which we should attend, and we do attend to them only by intense effort to do so. Here the effort takes the form of reinforcing the desired subject and inhibiting irrelevant subjects. Ability to exert oneself in this way is only acquired after practice. One cannot natively inhibit irrevelant stimuli which interest him. A child's attention will waver from one subject to another, and at the instant you think the child is listening to what you are saying he will break out with the remark, "Daddy, what is in your pocket?" A feeble-minded individual who has never been trained to resist irrelevant stimuli shows the same lack of control. Now if an individual did not have a tendency to oppose effort against distractions he would never learn to do so. All through life it would be absolutely necessary to attend to the most interesting thing and the only way to keep one's attention on a subject would be to make it more interesting than the distractions. When one starts to master a lesson the primitive tendency to persist in a line of activity once started comes in to dispel irrelevant distractions. When the distractions become too strong one can either remove them or add extra derived interests to his task to 'boost' him over the hard place. Each time he succeeds in dispelling a strong distraction it is easier for him to do the same thing the next time. He learns tricks to help him do so, such as straining his muscles, articulating words, etc. He uses these aids to help him over the difficult places but in so far as he is holding his attention by sheer force he is using a modification of the inherent characteristic of all organisms to oppose disturbances by increased effort.

Opposition to Innate Tendencies or Learned Habits

A man may awaken to the fact that he has an irresistable tendency to do some thing which is contrary to the moral codes of the society in which he is living or the doing of which would result in injury to himself. This tendency may be due to inheritance or due to some habit he has formed, the end result is the same. His whole organism impels him to do

the act, the system of forces of which he is composed is horribly unbalanced, all the weight is in favor of the act that would harm him; still he knows that if he does it he will receive the unanimous condemnation of his fellows or will suffer in some other way. If the realization of the consequences is vivid enough the tendency to do the act will be counterbalanced and the man will refrain. This is the usual type of activity in so-called moral decisions, when the individual is combating an inherent desire to do something or is fighting a habit he has learned. Victory comes without display of effort by making the consequences so forceful as to inhibit the performance of the act. In some cases however when some specific temptation comes the individual loses sight of the consequences, he believes he will not be caught, his organism and the outer stimuli affecting it all urge him to gratify his impulse. He feels that he will gain nothing by resisting except the maintenance of the integrity of his character. It is a battle royal with the odds greatly against the man and only the exceptional man will win. When the victory is won the victor feels that it was only through the greatest effort of his will-power. Such a man is the heroic type of which novelists write and poets sing. He is the ideal to set before the young, he is the standard by which we measure ourselves. How did he get the ability to display such force—to resist when all help had deserted him? Such a victory would never be won by a man who had never been schooled for the battle. The teacher of morality takes great pains to see that the child is given a proper chance to show its resistance to temptation but is also careful to help it across the hard place. No one would expect a child to fight a difficult moral battle, one never blames the child if it fails but blames the elders for their lack in properly guiding and helping the child. The adult who is weak morally is the one who has been so shielded that he never has had to fight a battle, or the one who was never helped so that he never won one. If there were no innate tendency to meet opposition with increased effort it could never be developed.

Summary

Every organism tends to maintain its integrity in the face of situations which would destroy it. Whether one explains the facts of the struggle which ensues from this state of affairs by reference to the concept of will or by reference to a tendency which developed through an evolutionary process, the nature of the struggle which the organism must put forth remains unexplained. Attempts to resolve all response into terms of stimuli must account for a variation in response with the same objective stimulus. This account has been made by reference to the physiological condition of the organism on the theory that every stimulus, besides the direct discharge which it causes, diffuses energy throughout the organism and leaves it in a different condition. This difference in condition results in the second response to the same objective stimulus being different from the first. What is meant by physiological condition (or the correlative psychological term dynamogenesis) needs to be more carefully defined and this paper is an attempt to define one phase of this explanation.

The thesis of this paper is that effort in the sense of a tendency to oppose any stimulus which would destroy the integrity of the organism is a reflex response. Given an inimical stimulus plus the failure of the normal response of the organism to that stimulus to remove it, an increased effort will result.

The paper proceeds on the assumption that the reason for the presence of any trait can be referred to biological variation and selection, the thing which is required is to show that the trait exists at various stages of organic life and that complex manifestations can be referred to the elementary forms and explained as developments from them.

Following this line of reasoning it is shown that the increase of effort to the stimulus of failure appears in an organism as elementary as the stentor, in higher animals, in infants at birth, in a nerve muscle preparation, in muscles intact in the organism, and finally in complex human activities such as resisting distraction. From these facts the conclusion is

drawn that effort is an immediate response to the stimulus of failure.

The exhibitions of effort in such complex mental processes as solving novel problems, persisting in practice, effort in attention and in moral conflicts are then traced as developments of the reflex tendency present at birth to oppose resistance to free activity.

Much work has been done in determining the laws of retention and reproduction because it was felt inadequate to explain present activity by a general reference to past impressions. Just so, psychology cannot rest with the explanation that the response depends upon the physiological state of the organism. The physiological state (set of the organism, directions received, or any other term which may be used) certainly depends upon certain laws which are discoverable through proper research. This paper in an attempt to formulate one of these laws.

A COMPARISON OF COMPLETE VERSUS ALTERNATE METHODS OF LEARNING TWO HABITS.

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In the main, the study of habit formation has been limited to the study of one or another single kind of habit. True, in human psychology interest has widened from a technical study of a single learning process to include the investigation of two or more, and in animal psychology a few isolated researches have been devoted to one aspect of the matter; but the early researches upon the interference between habits and the more extensive studies of the problems of transfer of training seem not to have stimulated much activity along still other lines of possible investigation in the matter of the development of more than one habit. Putting it very generally, one might divide the past lines of interest in multiple habit formation into (1) the investigation of the relations between one process of learning and a simultaneous process of learning, and (2) that of the relations between earlier and later learnings (of different problems). The former interest has been little shown in animal psychology, and in human psychology only after the latter interest has been rather exhaustively handled. The latter embraces well-known questions as to the transfer of training.

The work here to be reported was a preliminary comparison between the practice methods referred to in (1) and in (2) above. For a subject that is to learn two different habits is it more economical to practice on them both at the same time as nearly as may be, thus learning them together or 'alongside' each other, or to practice on one only after the other has been completely learned by itself? To approach a reliable answer to this rather general question different

[1] The experimental work was done in the Oberlin College Laboratory.

types of subjects and of habits were used. This paper will summarize these separate studies under the headings:

I. Maze Running by Rats;
II. Maze Running by Children;
III. Maze Running by Adults;
IV. Card Sorting by Adults;
V. Adding by Adults.

While this research was in progress Pyle's brief article appeared[1] in which he shows that experiments in card distribution lead to the inference "that it is not economical to form at the same time two mutually inhibitory sets of habits. The better procedure is to form one, and then the other." The present study may then be taken as a research similar to Pyle's but extended over a wider range of habits.

I. Maze Running by Rats

Nothing, so far as the writer is aware, has been done with animals on the question as to the relative economy of Complete and Alternate methods in double habit formation.

The general method used by the writer embraced two procedures: (1) that of training one group of white rats in a single maze *R*, and when that was completely learned in a second maze *L*; (2) that of training a second group of rats in the same *R* and *L* mazes alternately, *e.g.*, if maze *R* be used on Monday, Wednesday, Friday, and Sunday of a given week, maze *L* was used on Tuesday, Thursday, Saturday, and the next Monday. The first method of training will be called "Complete," the second, "Alternate." As implied, single daily trials were set. The animals had been previously accustomed to a feeding at 4:30 P.M., the hour adopted for the experiments, and for a few days before the beginning of the experiment were fed in the food box to be connected with the maze. Uniformity of hunger conditions from day to day were obtained by letting the animals feed as long as they would (less than half an hour) after each day's run, then removing them to the nest box where they had no food until the next run, twenty four hours later.

[1] W. H. Pyle, 'Transfer and Interference in Card-Distributing,' *Journal of Educational Psychology*, 1919, 10, 107–110.

The mazes were of cork-composition flooring, galvanized iron partitions, and glass tops; and all runways and alleys were 4 inches in height by 4 inches in width. The entrances were closed behind the animals by raising a galvanized iron piece hinged at the floor.[1]

The particular patterns of mazes used are shown in Fig. 1. They were exactly inverse to each other. It was believed

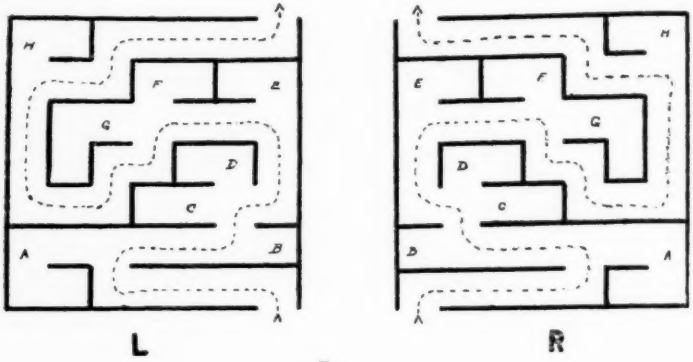


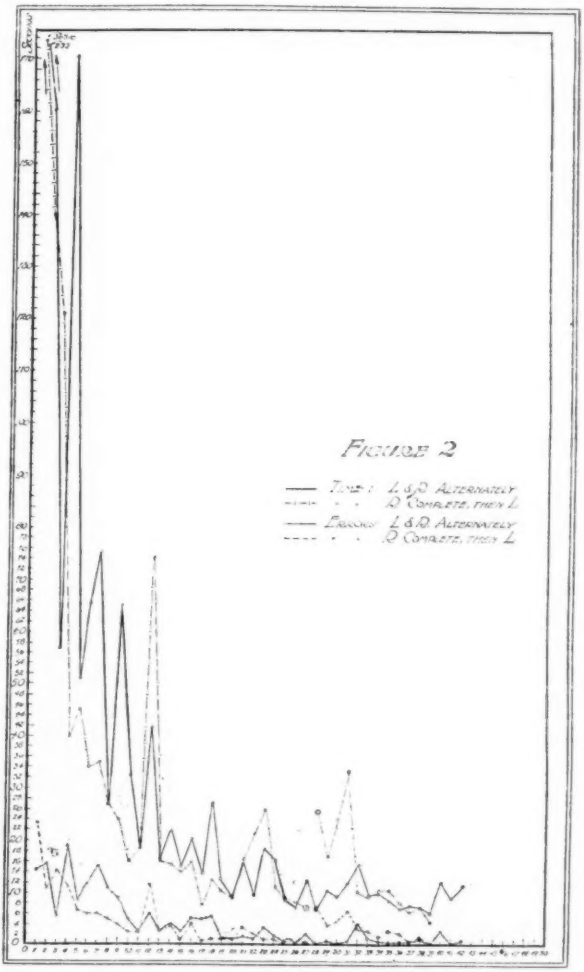
FIG. 1.

that the identity of pattern when inverted would be unimportant to the animal subject, and it had the advantage of making the mazes equivalent in difficulty. It will be observed incidentally that the eight culs-de-sac furnished a variety in position (*a*) with reference to runway, and (*b*) with reference to each other. As preliminary to further studies into the respective influence of different sorts of culs-de-sac notes were taken regarding the functioning of these in this experiment, but the data will not be presented in this place.

In order to provide as complete controls as possible a single litter of white rats was used, one half of the litter serving as the controls for the other half. This necessarily made the number of subjects small, six being used, three in each group. They were exactly eight weeks old at the beginning of the experiments.

[1] For details of construction of these and other mazes in the Oberlin laboratory see *Psychol. Bull.*, 1919, **16**, 223–230.

The data obtained for both groups in time consumed and errors made for the various runs are given graphically in Fig. 2. The 28th trial marks the first practice by the Com-



plete group (group learning by the Complete method) in maze *L*.

Comparison of the numerical records of the two groups would show little difference between the methods of Complete and of Alternate learning in regard to total number of trials required. The Complete group shows respectively, 37, 37, and 36 trials (total, 110); the Alternate group, 30, 49 +, and 32 (total, 111 +).

As to type of curve it is to be said that not as much difference was found as would perhaps have been expected. The curves for the subjects learning the *R* maze Completely before being given the *L* maze conform in a general way to the type found in numerous experiments with a single maze, if we take them as far as the twentieth trial. The only unusual feature is the highly increased time and errors at the twelfth trial—attributable to rat *C*'s relapse alone. In the twenty-first to twenty-fourth trials the slight rise of curves is due to the fact that rat *J*, having learned maze *R*, was resting, and the average represents only the achievements of the other two rats. The twenty-eighth trial was the first one on the new maze *L*, and the curves are accordingly high. That they are not decidedly higher is evidence of the transfer generally found in the learning of one habit just after the learning of a somewhat similar one. The average time taken for the first trial in maze *L* is not as great as that for the eighth trial in the previous maze *R*; the average number of errors in the first trial in *L* is only slightly greater than that for the fifth in *R*. To what extent were transferred factors operating and to what extent was there interference? The former seem to have been more in evidence than the latter. Apparently, the need is here indicated for a careful analysis of the degrees and sorts of transfer of different features of the whole maze learning procedure.

For the Alternating group the time curve shows again the general form of the learning curve for the white rat in the maze problem. The error curve is to a lesser degree of that type. As is to be expected, these curves for learning Alternately two mazes show poorer records than do those for rats learning the *R* maze only, *i.e.*, longer times and more errors. This difference in amounts of scores made, however, is not very great.

A feature that appears more definitely is the difference in regularity and irregularity in the curves for the two groups of rats. It is especially evident in comparing the performances in trials 2 to 20 inclusive. The curves for the Complete group are fairly regular and smooth, those for the Alternating group decidedly more irregular, and the time curve so throughout its length. That this feature was not due to a difference in difficulty in the two mazes in alternate use is shown by the fact that the changes are not in the form of a regular alternation between better and poorer scores. Consider such successive changes as in trials 5–6–7–8, in 9–10–11, in 18–19–20, or in 23–24–25–26. To obtain a more definite statement of the differences in amount of regularity in the work of the two groups the writer hit upon the following method:[1] (a) finding the amount of improvement or loss between each two successive trials for each animal in time and in errors; (b) summing all changes of both sorts (both gains and losses) for each animal; (c) averaging these totals for each group; (d) determining the average number of trials taken in each group; (e) writing the number obtained by (c) over that obtained by (d), to express the group average of changes between each two successive runs. (The same method can, of course, be adapted for application to individuals.) Let us call this the "Index of Irregularity." The relation between the two groups may then be exhibited in the form of a fraction or a ratio between the two indexes of irregularity. In this way the Alternate group shows the greater irregularity in reduction of time consumed by the ratio 24.51: 21.58. The same group shows a very slightly greater irregularity in elimination of errors, 3.48: 3.41.

The writer cannot refrain from remarking that had the first trial of subject *J* of the Complete group been not so disproportionately great in time and errors, the differences

[1] Application of the method of average of deviations from the average of performance for each group (the well known "A. D.") was tried and discarded at once—the two groups gave the same A.D. for errors, 4.32. The large difference in the initial trials of the two groups (time and errors for Alternate group being 233.0 and 14.3 to 365.6 and 23.6 for the Direct group) is enough to offset a very large amount of greater irregularity by the Alternate group, if the ordinary A.D. be the measure used.

between the two groups would have been materially increased. Time on first trial for each subject of the Alternate group was *E*–92, *T*–402, *A*–205; for subjects of the Complete group, *H*–108, *J*–845, *C*–144; errors on first trial for Alternate group were *E*–8, *T*–17, *A*–18; for the Complete group, *H*–9, J–54, *C*–8.

We would seem to be warranted in concluding that for white rats learning two different mazes with one run daily, it is more economical to practice one Completely, then the other, than to run them Alternately. This greater economy is shown in the form of a greater regularity of performance. As to a difference in total number of trials required by the two methods the data are not conclusive.

II. Maze Running by Children

Surely one important justification and *raison d'être* of the science of animal psychology is to be found in the possibility that principles and laws empirically arrived at in this field may be found applicable in some degree to human psychology and education—fields more complex and difficult of experimental as well as theoretical analysis. It may be safely stated in this connection that such application from one department of psychology to another will be the more warrantable as the materials and methods involved in the two cases are the more nearly identical. It was in accordance with this principle that the author made a study of maze learning by young children.

The eight children used were attending a kindergarten and were in their fifth or sixth years (four or five years old). In this experiment it was necessary because of lateness in the school year to have the child make two runs daily about twenty minutes apart.

The material used was a multiple unit set of screens 4 feet by 3 feet hooked end to end to form the partitions,[1] and was set up indoors on the floor of a large room. To serve as incentive, silk flags on a small upright stand were shown the children and then 'hidden somewhere inside,'

[1] Described elsewhere, *cf. supra*, note p. 114.

and the children were sent in to find them. This artificial incentive quickly gave place to the 'problem solving' interest which persisted throughout in good strength.

On account of the limited floor space available it was impracticable to have two entirely separate mazes erected; and the same condition necessitated the employment of a simpler pattern than the two used for the rats. Figure 3

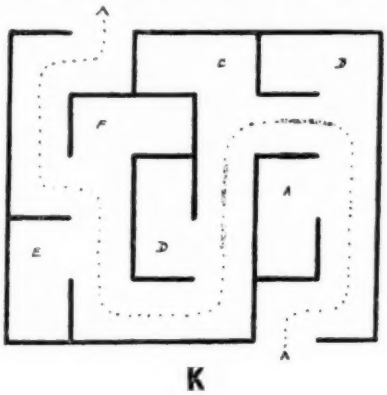


FIG. 3.

shows the ground plan of the kindergarten maze. As one problem the subjects learned to run this maze forward, in direction indicated by arrow heads and passing culs-de-sac in alphabetical order (called problem *F*); the other problem consisted in learning the reverse path, passing the culs-de-sac in the order *F-E-D-C-B-A* (called problem *B*). Similarly to the plan employed with the rats, the method here used was to have one group of children practice problem *F* only until learned Complete (indicated by three successive errorless runs), then the problem *B* only; and to have the other group practice Alternately on the two problems, taking problem *F* first on each day and *B* second.

The data obtained for both groups in errors and in time consumed for the runs are plotted graphically in Fig. 4. The seventeenth trial marks the first practice by the Complete group upon the problem *B*, the subjects who had learned problem *F* earlier continuing to run on it until this trial.

Comparison of the numerical records of the two groups would show some slight advantage for the Complete method in so far as the number of trials required is the criterion, the

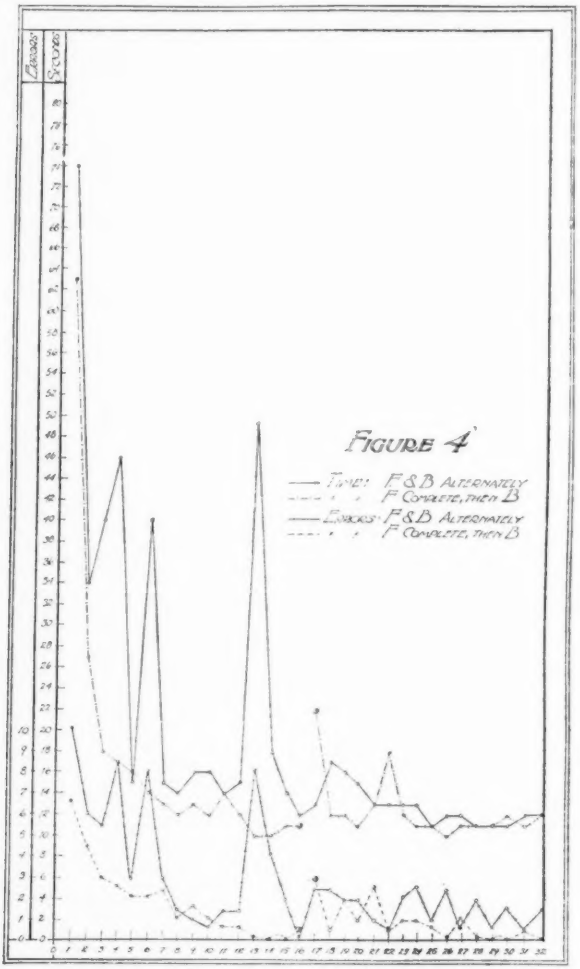


FIGURE 4

children learning by this method requiring respectively 33, 32, 28, and 23 trials as against 34, 37, 30, and 35 + trials for the other group.

The type of curve is again of the well-known negative acceleration kind for both groups.

The feature that again strikes the eye is the difference in regularity or irregularity in the curves for the two groups of subjects. Using the fraction described above in connection with work with rats, it is found that the respective "indexes of irregularity" compare as follows: the Alternating group again shows greater irregularity over the Complete group in the reduction of time consumed by the ratio, 6.62: 3.63; the same group shows a greater irregularity in elimination of errors, by the ratio, 7.00 : 3.44.

Another difference between the work of the two groups is to be found in the amount of errors and time shown for single trials. Consider especially the differences in errors in the trials numbered 2 to 8, 11 to 15, 22 to 26, 28 to 32, and the differences in time in trials numbered 2 to 4, 6 to 16, 18 to 20. The group learning by the Complete method showed fewer average errors in 25 out of 32 trials and shorter average time in 22 out of 32 trials.

III. Maze Running by Adults

Another approach to the general problem of the research was made by using adult human subjects with pencil mazes, and with a somewhat different program.

Four students of college grade in a summer session were enlisted as subjects. They will be denoted by initials, *H*, *K*, *B*, and *W*.

The mazes were constructed as follows: the design of each maze (see Fig. 5) was laid out on cardboard and then with a narrow band saw cut out of 'beaver board.' This was given two coats of shellac to produce sufficient hardness and smoothness of edges. The 'beaver board' was nailed firmly over a piece of cardboard placed upon a wooden base. The runways were $^1/_4$ inch wide and $^1/_4$ inch deep, and had the smooth cardboard for their floor. Two of the mazes (*S* and *s*) were designed on a rectangular and straight line plan, to make a suitable problem for the development of two habits, and were respectively $8 \times 9^1/_4$ inches and $8^3/_4 \times 9^1/_4$ inches

in outside dimensions. The other two (*R* and *r*) were designed on lines similar to one another but quite distinguishable from the first two: they were of circular outside plan with radius of $4^1/_8$ inches, and the runways were arcs of the same curvature. A stylus was fashioned by rounding the end of a $^3/_{16}$-inch round brass rod, 6 inches long. A rubber

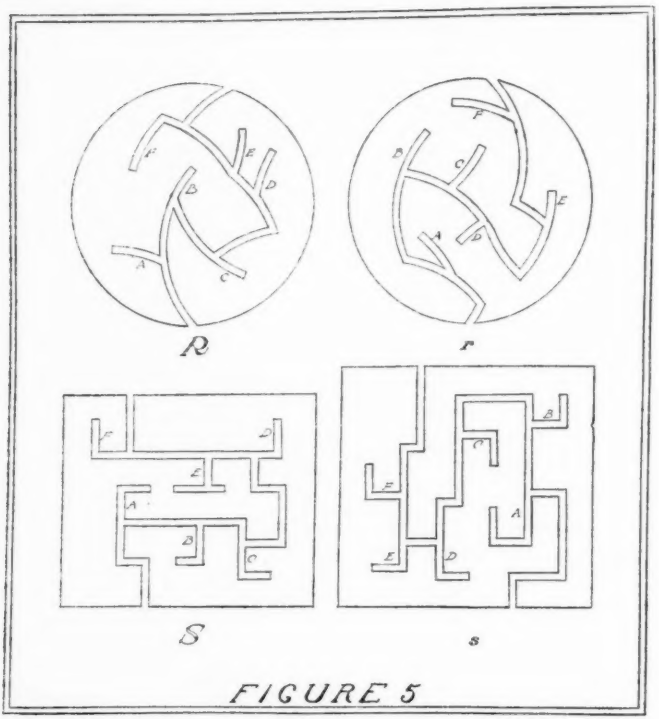


FIGURE 5

band was wound around the stylus 2 inches from the lower end. The stylus moved easily in the runways when held vertical, but was of sufficient diameter to prevent too great looseness and loss of contact with sides of runways.

The program of the experiments was arranged so that each subject might serve as his own control, by having him learn one pair of mazes by the Alternate method, the other

pair by the Complete method. Instead of the trials being distributed over a long series of days, as had been done with children and especially with rats, the maximum of 40 trials allowed to each problem was given all at one sitting (of 45 to 60 minutes). The order of use of the two pairs of mazes, and the order of use of the two methods was varied, as seen in Table I.

TABLE I

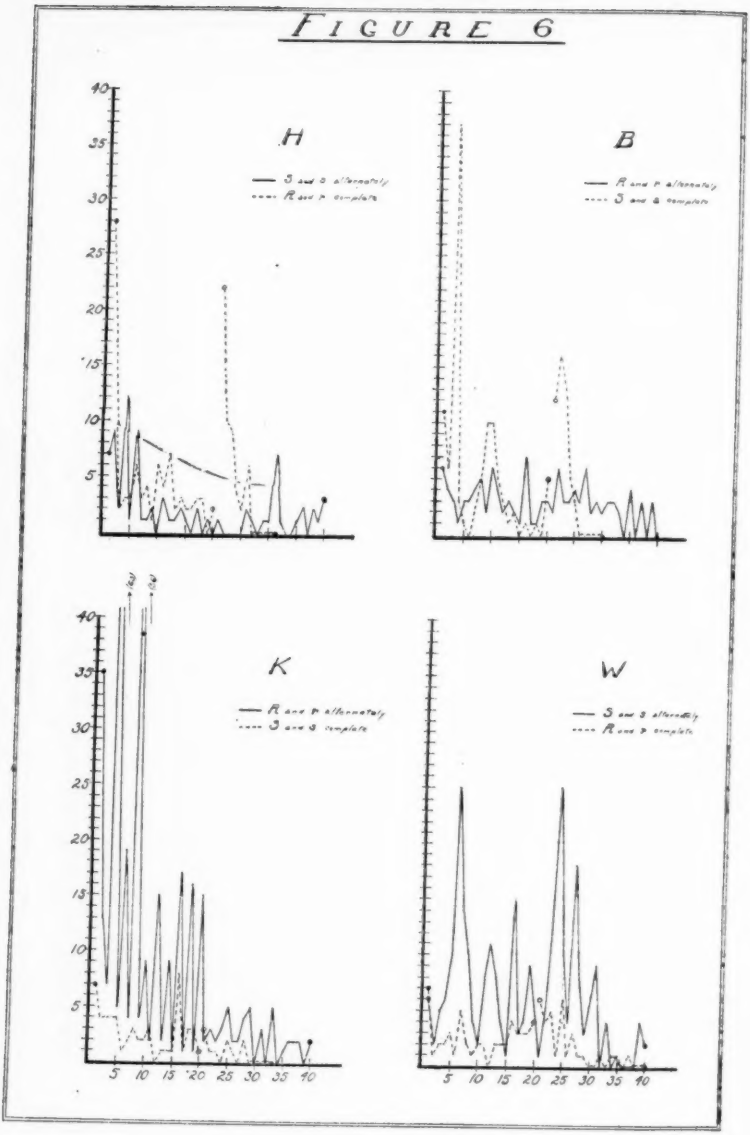
SHOWING PROGRAM OF SITTINGS

Subject	Tuesday	Thursday
H.....	Mazes *R* and *r*, Complete method	Mazes *S* and *s*, Alternate method
K.....	Mazes *R* and *r*, Alternate method	Mazes *S* and *s*, Complete method
B.....	Mazes *S* and *s*, Complete method	Mazes *R* and *r*, Alternate method
W.....	Mazes *S* and *s*, Alternate method	Mazes *R* and *r*, Complete method

The subjects were uninformed throughout as to the object and the exact methods of the experiment and as to the order in which the mazes were to be used. After every trial the experimenter removed the maze and made a "business as of changing mazes" before placing maze for the next trial. This procedure was followed whether the same or the alternate maze was to be used. Remarks or questions by the subjects as to the apparent sameness or difference of mazes used in successive trials were not answered. Thus in addition to learning mazes in the usual sense the subject had to discover inductively their number and the order in which they were set. (As mentioned above, the entrance paths to all mazes were different—to furnish a clue at the beginning of each run that could sooner or later become definitely recognized and used.) In operation this was found to have considerably increased the difficulty of the learning and to have introduced important ideational elements that may be partially responsible for the minor differences in results between this and preceding parts of this research.

For the experiment the subject was seated at a table upon which the maze was placed, with a screen fixed above it to shut off vision of it. The instructions given the subject were as follows: "You are to take this brass stylus (shown) in your fingers much as you would a pencil, but holding it

FIGURE 6


H
S and o alternately
R and r complete
B
R and r alternately
S and s complete
K
R and r alternately
S and s complete
W
S and s alternately
R and r complete
40
35
30
25
20
15
10
5
5 10 15 20 25 30 35 40

vertical. Do not place fingers below the rubber band. As you hold it I will insert the point at the beginning of a groove cut in a wooden floor, which you are not to see. You are then to move the stylus within this groove until you reach a point at which I say, 'Stop!' Time will be taken for the trial but you are not to feel hurried. Three points are to be remembered: Do not lift the point of the stylus from the floor of the groove; always keep the stylus in strictly vertical position, never let it slant; never let your fingers or any part of the hand touch the floor." In actual operation the subject's stylus upon reaching the exit went down off the edge of the one inch base board.

The results of this experiment are best presented graphically in Fig. 6. Only curves for the errors are shown. The time and error curves were in every case practically identical, as the human subjects did not show the rapid pick-up of speed shown by the rats, *i.e.*, a relatively greater elimination of surplus time than of errors. It will be seen that with the subjects practicing by the Complete method first (*H* and *B*) a great loss of time and a great number of errors accompanied the first runs on each maze learned by this method. The slightly better performance by these same subjects when using the Alternate method later is, however, possible of interpretation in terms of practice—practice on the first two mazes being advantageous for practice on the later two, being an evident case of transfer at least of the more general elements in the learning situation. This is confirmed by inspecting the curves for *K* and *W*, who used the Alternate method first. In both of these subjects the improvement in learning two mazes Alternately is slow and, what is most

TABLE II

SHOWING INDEXES OF IRREGULARITY IN ELIMINATION OF ERRORS

	By *C.* Method	By *A.* Method
Using *C.* Method First:		
H	3.55	2.25
B	4.36	2.00
	7.91	4.25
Using *A.* Method First:		
K	1.03	11.37
W	1.42	5.35
	2.45	16.72

striking, very irregular. Remembering its limitations, we may again employ our index of irregularity to bring out the last point. See Table II. It is also instructive to note how rapidly the second habit by the Complete method was learned, in all cases.

IV. Card Sorting by Adults

So far the question as to the relative efficiency of Complete and of Alternate methods in practicing two habits has been studied in connection with maze learning. Certain general principles have been found to hold for maze habits for different kinds of subjects with different kinds of maze materials. The question arises, can the findings be demonstrated for other sorts of habits? Since the running of a labyrinth is a typical sensori-motor or perceptual-motor habit, it occurred to the experimenter that it might be enlightening to apply the same methods of approach to some other style of perceptual-motor habit. The one chosen, card sorting, possessed the advantage of being a familiar one in psychological literature, having been already studied somewhat with regard not only to questions concerning single learning processes but also to some questions with respect to the formation of multiple habits.[1]

In the present series[2] the general program was similar to that used in maze-running experiments with adults. The material needed was two packs of cards of quite different kinds. For one a 'flinch' deck was used which, with all numbers of 11 and higher discarded, furnished ten cards each for the numbers 1 to 10, one hundred in all. For the other pack, one hundred blank cards of size, shape, and general 'feel' similar to the 'flinch' cards were obtained, and upon them were printed autographs in script by means

[1] For studying the interference of habits it has been used by Bergström, Brown, Culler, Pyle. The study of Pyle, referred to above, which is almost identical in some regards with this section of the present paper, appeared while these experiments were in progress. The corroboration of his findings has its own value, and hence this section is included in the paper.

[2] For the data on the card sorting experiment the writer is indebted to Miss Helen G. Smith.

of rubber stamps obtained from men on the campus, one autograph for each ten cards, ten autographs for the whole pack. The general procedure was to have each subject use one of the packs for learning to deal to two different distributions or lay-outs on the table by one method (Complete or Alternate), and to use the other pack for learning two different distributions by the other method. See Table III.

TABLE III

SHOWING DISTRIBUTION PATTERNS USED

With "flinch" cards:

Pattern *F*					Pattern *f*				
3	8	4	7	10	2	8	10	5	3
6	9	1	5	2	7	1	4	9	6

With autographed cards:

Pattern *A*					Pattern *a*				
J	S	C	L	M	G	B	N	L	F
N	G	R	F	B	C	J	S	M	R

The subjects used were four college students, Juniors and Seniors, referred to as Br, Bu, P, and H. They all coöperated well throughout.

They worked at the experiment daily for ten days. They were given a total of twenty-five deals in which to learn each lay-out pattern; but these deals were arranged in the two different orders, the Complete and the Alternate. Table IV. shows in detail the program of the work as carried out. The letters denote the lay-out patterns, as given above in Table III., the figures indicate the number of deals on each day to that lay-out.

The subjects were instructed to make each deal as rapid as possible and were warned that time would be taken. A misdeal had to be corrected before continuing.

The graphic method again recommends itself as the clearest way of presenting the results. See Fig. 7, in which the individual records are shown separately.

It is to be observed at once that the Alternate method of practice in dealing to two different distributions is unquestionably inferior to the Complete method. This is strikingly true in the matter of actual amounts of time taken, shown by the lower vertical positions on the graphs. What is less

FIGURE 7

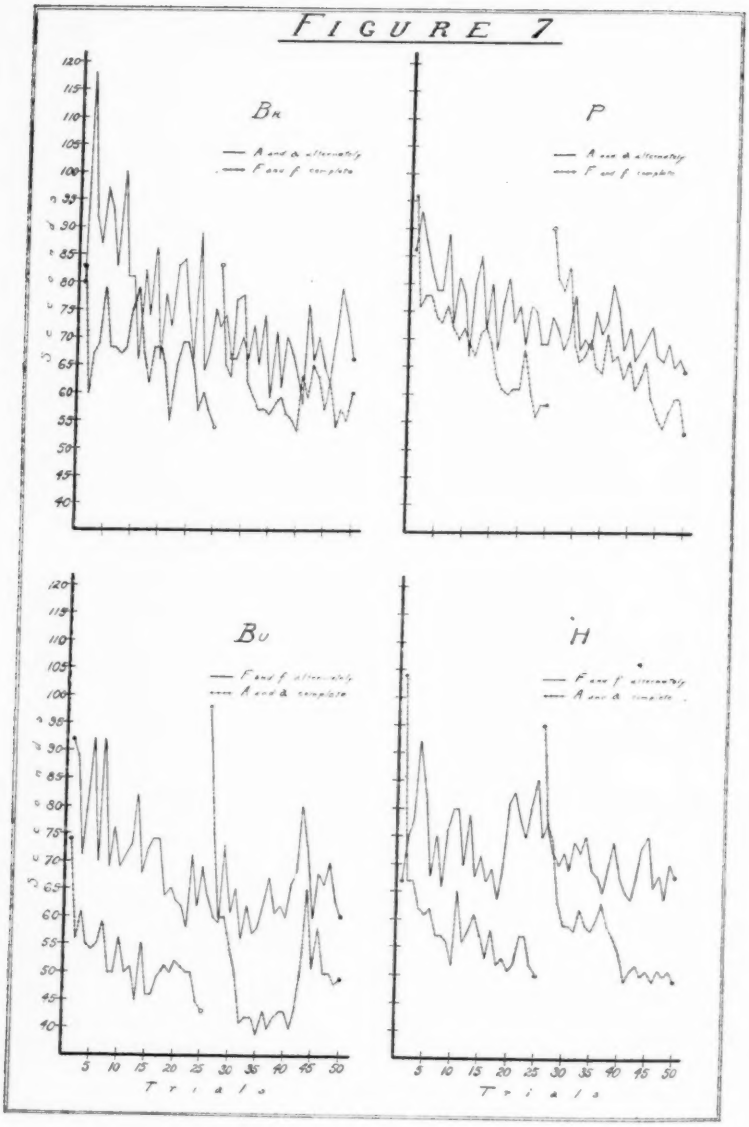


TABLE IV

SHOWING PROGRAM OF CARD-SORTING EXPERIMENTS

Subjects	First Day	Second Day	Third Day	Fourth Day	Fifth Day	Sixth Day	Seventh Day	Eighth Day	Ninth Day	Tenth Day
Br.	F^{10}	A^5 and a^5 altern.	F^{10}	A^5 and a^5 altern.	F^5 then f^5	A^5 and a^5 altern.	f^{10}	A^5 and a^5 altern.	f^{10}	A^5 and a^5 altern.
Bu.	A^{10}	F^5 and f^5 altern.	A^{10}	F^5 and f^5 altern.	A^5then a^5	F^5 and f^5 altern.	a^{10}	F^5 and f^5 altern.	a^{10}	F^5 and f^5 altern.
P.	A^5 and a^5 altern.	F^{10}	A^5 and a^5 altern.	F^{10}	A^5 and a^5 altern.	F^5 then f^5	A^5 and a^5 altern.	f^{10}	A^5 and a^5 altern.	f^{10}
H.	F^5 and f^5 altern.	A^{10}	F^5 and f^5 altern.	A^{10}	F^5 and f^5 altern.	A^5then a^5	F^5 and f^5 altern.	a^{10}	F^5 and f^5 altern.	a^{10}

apparent in the curves but is shown in the numerical data is also a greater irregularity in the rate of progress in learning by the Alternate method. Table V. gives the warrant in figures for both these conclusions.

TABLE V

SHOWING SCORES IN CARD SORTING

Subject	Method	Average Time Taken (Seconds)	Index of Irregularity
Br.....	Complete	63.9	5.7
	Alternate	74.8	9.5
Bu.....	Complete	51.6	5.7
	Alternate	68.6	6.9
P.....	Complete	67.4	4.2
	Alternate	74.0	5.3
H.....	Complete	58.7	4.7
	Alternate	72.5	5.1

What has been demonstrated for maze learning is found to hold true also for card sorting. It would seem to follow that the principle would be found to apply to all forms of true sensori-motor or perceptual-motor habit formation.

V. ADDING BY ADULTS

If certain principles are found to hold true of a particular region in the whole field of learning, an important question then arising is, will they hold true of all learning in general? To make one further step in this logical direction, the author sought an answer to the fundamental question of this research in connection with learning on a 'higher' plane than the perceptual-motor. As a more 'purely mental' process that

is yet sufficiently of the habit type to be easily recorded and measured objectively, numerical computation suggested itself. Addition was taken as a particular form of computation the improvement in which might serve as an interesting task to students, especially in view of the practical value of adding ability.

The subjects were ten summer session students of college grade, members of the writer's class in the psychology of training. The adding work was given during the first few minutes of each class hour, the class meeting usually five days in the week. The students were fully informed of the problem in hand; in fact, it was treated as a concrete side of the material of the course. Their daily individual and group records were exhibited at the following meeting, both numerically and graphically. The writer was convinced, and was so assured by the students, that their interest in the adding was throughout high, generally being keen.

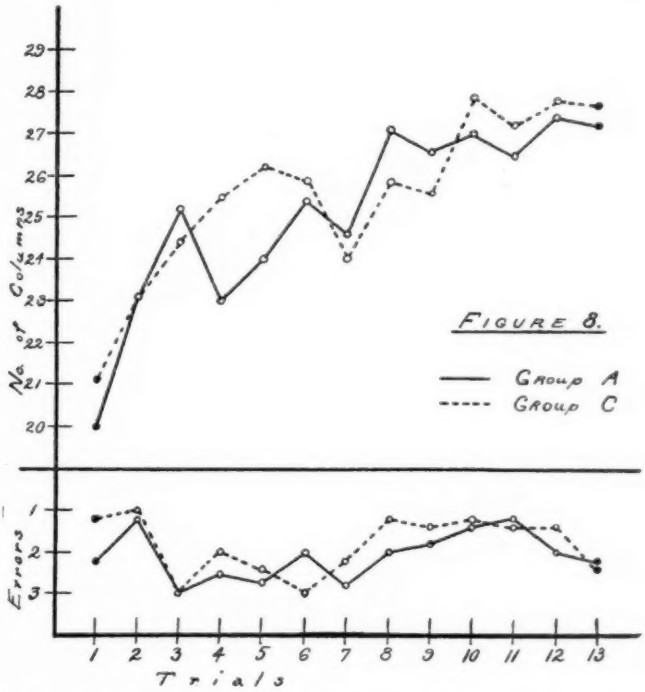
The material used consisted of mimeographed addition blanks, with thirty examples on each sheet, each example consisting of ten two-place numbers in vertical order. Six sets of the material were provided, and the sets used in rotation.

The experiment was conducted as follows: One copy of the examples to be used for that day was given face down to each student at his desk. At a signal, all turned their papers over and immediately set to adding, continuing until the stop signal was given aloud at the end of five minutes.

Both in order to eliminate some of the elements of psycho-physical adjustment to the work, in a sense somewhat extraneous to the problem at hand, and in order to have some basis for dividing the class into two groups as equal as possible, a preliminary series of trials in simple addition was given. In these trials the subjects added the numbers vertically digit by digit and column by column. The results were taken in terms of single columns or half columns added. This was done for the five-minute period at thirteen successive class hours. On the basis of the individual scores made the experimenter divided the class into two groups of

five each, for the formal experimental series. Fig. 8 gives the average scores of the individuals as so grouped.

For approaching the question as to the relative efficacy of learning two kinds of addition by the Complete or by the Alternate procedures, it was necessary to fix upon addition methods that, while having some elements in common, would



yet differ in important ways. Moreover, the addition methods had to be novel. The plan hit upon was to use for the one method or habit to be learned, the adding of two-place numbers horizontally, from left to right, adding the units first and then the tens. The other habit decided upon was the adding of the two-place numbers vertically, but by grouping them: adding first the odd-place numbers together and noting down the sum, then the even-place numbers likewise. Thus with the

blank partly given in Table VI, the horizontal method would involve adding successively the digits 4–5–2–9–8, etc., for unit place in the sum, and 8–3–5–7, etc., for the tens and hundreds; the vertical method would require adding the digits 6–9–7–5–1 and 3–5–7–4–9 for the total 308 of the odd numbers, and then adding 8–4–2–3–4 and 6–3–6–2–8 for the total 271 of the even numbers. As in the simple addition in the preliminary series a complete sum obtained horizontally counted as two columns; a sum of only odd-place or of only even-place numbers obtained vertically counted as one column.

TABLE VI

SHOWING PART OF SAMPLE ADDITION BLANK

84	35	52	79	18	44	63	85	59	27
91	—	—	—	—	—	—	—	—	—
23	—	—	—	—					
45	—	—							
62	—				Etc.				
77									
34									
59									
68									
36									

The program followed was for one group (*C*) to practice the horizontal habit for seven trials in succession then to practice the vertical method for the remaining seven trials; and for the other group (*A*) to practice at horizontal adding on the first, third, fifth, etc., days, and at vertical adding on the second, fourth, sixth, etc., days.

For simplicity's sake the results of the formal series will be given in terms of number of columns added, corrected for accuracy by deducting a half column for each error.

It was early observed that these two habits were not of equal difficulty (as had apparently been the case in all the preceding experiments), the vertical habit being clearly the harder. The gross average number of columns added vertically by group *A* was found to be only 83.8 per cent of the number added horizontally, the corrected average of the number added vertically being 84.3 per cent of the corrected average of the horizontal additions. For group *C* the corresponding uncorrected and corrected averages bore the

ratios 89.6 per cent and 89.9 per cent, respectively. In order, then, to be able to show the relations between the two habits it was necessary to make them more commensurable by using the above ratios of corrected averages for the two groups as bases for weighting. Thus, the group *A* average for each trial by the vertical method was considered as 84.3 per cent and raised to 100 per cent; the group *C*

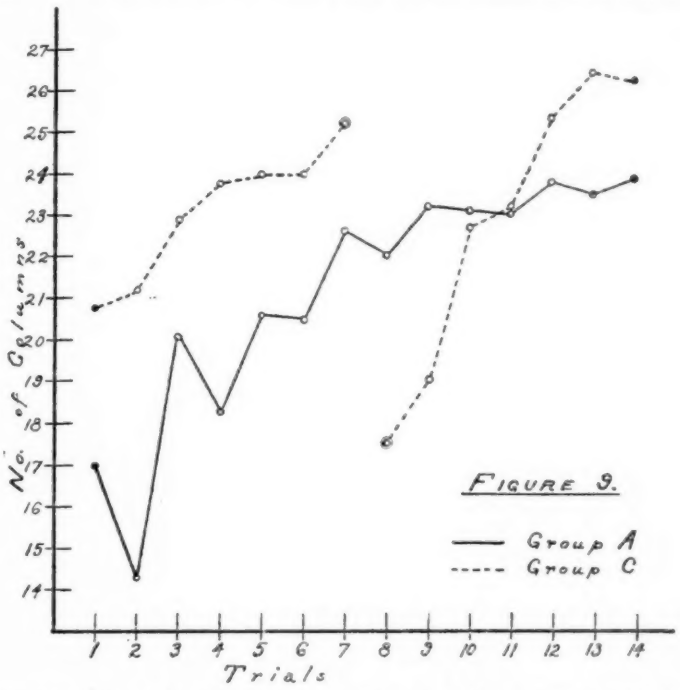


FIGURE 9.

average for each trial by the vertical method was similarly increased from 89.9 per cent to 100 per cent.

The resulting data for both groups by both habits are plotted graphically in Fig. 9. Here we see a very clear superiority in the work done by the group adding by the Complete method. The curve showing their horizontal adding is consistently high. What is more striking, however, is the extreme rapidity of improvement in vertical addition

when once it was undertaken and practiced without interruption. One doubtful feature of the record is the interpretation of the relatively good performance by the *C* group at the very first trial. If our preliminary scores for the two groups are reliable (see Fig. 8) such high initial score is not due to greater initial general ability in adding.

In the matter of regularity in improvement the curves speak more clearly than numerical figures. The index of irregularity found for group *A* is 1.3, that for group *C* is 1.5. Unquestionably, this difference does not speak for a lesser irregularity in improvement for *A* so much as for the great drop by the *C* group in starting the learning of the second habit. In any case the difference is small, and the outstanding feature of the results is the much more rapid progress shown by the group learning one habit at a time.

Summary

We have approached the question as to the relative efficacy of learning two habits by practicing them alternately (the Alternate method) or by getting one to some extent fixed before practicing the other (the Complete method). The approach was made with the use of mazes for rats, children, and adults, then extended to include another perceptual-motor habit, card sorting, and further still to include a habit involving very little of the motor element, addition.

The particular technique of the different experiments was intentionally varied considerably: (*a*) in temporal distribution of trials, (*b*) in stage at which shift was made from one to the other habit by the Complete method, (*c*) in arrangement of controls—division of subjects into groups, (*d*) in methods of scoring, (*e*) in incentives used, (*f*) in subjects' previous familiarity with the habits to be learned, (*g*) in subjects' knowledge of the number and order of the habits to be learned, (*h*) in subjects' knowledge of the nature of the problem investigated. Thus, the general results found may be considered as independent of particular details of technique and to be of general bearing.

For results, it has been found that in all the forms of double habit formation studied, learning by the Complete method is more economical than learning by the Alternate method. This is indicated in the different sets of experiments in terms of the different criteria of efficiency respectively applicable. They include: (*a*) the number of trials necessary to fix a habit, (*b*) the degree of regularity in improvement, (*c*) the average amounts of scores made on individual trials, (*d*) the rate of acceleration of improvement.

THE TONAL MANIFOLD

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Psychologists have often resorted to graphic representations, both bi- and tri-dimensional, in endeavoring to express the interrelationships which obtain among the concurrent aspects of elementary sensation. The most successful of these attempts has been in the field of vision where the color triangle, the color pyramid and the color cone are well known as means of setting forth the dominant features of the chromatic and the achromatic series of visual sensations. Similar schemes have not been wanting for the other senses, but no very useful representation has become current to elucidate the characteristic features of auditory sensation. Sometimes the tonal manifold has been represented as a straight line to suggest the rise of pitch from low to high tones, and sometimes a spiral has been used in order that the recurrent similarities of the octave might be indicated by points directly above one another in the spiral progression. But the latter succeeds only in emphasizing the recurrent likeness of octaves; for it fails to distinguish the similar relations obtaining between other consonant intervals. In the light of recently acquired knowledge concerning the volume and the intensity of sound, the relations of pitch and consonance can no longer be regarded as the dominant features of the tonal manifold, and it is now possible to regard the octave-quality of a tone as perceptual in its origin. Although tonal consonance is still a debatable question, it seems fairly obvious, upon analysis, that the octave, or any other consonance, *subsists* in the relation of a musical interval; and that its elemental nature is therefore either an implicit relation, as Stumpf understands it to be, or the product of an implicit or an explicit act of perception in which not one tone alone but two different tones are involved. In neither case

does a quality of consonance or an octave-character attach itself directly to the simple element of tonal experience, as does, by contrast, its pitch, its intensity, or its volume.

Unless we revise our whole conception of sensory analysis, the characteristic aspects of an elemental sound are now recognized to embrace at least four attributes; namely, pitch-brightness, volume, intensity, and duration. Although each of these is a variable, the particular degree of each which attaches to any given sound is determined once and for all by the psycho-physical conditions under which it exists. The octave-quality, on the other hand, is a characteristic which attaches equally to all tones within the musical range when an appropriate reference has been made to another tone of the series. Furthermore, a particular tone, though it can have octaval relationship with but two other tones, one below and one above it in the series, may establish numerous consonances with various tones both above and below it in pitch.

In addition to the octave-quality of a tone there is also a debatable quality which is supposed to enable one to assign a tone to its appropriate place with reference to certain fixed regions of the scale. This would explain the occasional ability of a person to judge the 'absolute pitch' of a tone, and it has also been thought to explain certain outstanding regions of pitch with which the vocal qualities seem to be associated. Whether a c-ness, d-ness, e-ness, etc., of tones is immediately apprehended without involving a somewhat complicated act of perception is a question we shall not here attempt to decide, but in view of the fact that Oriental peoples employ scales in which these harmonic designations have no significance, it seems best to reserve judgment for the present and test the possibility of some other explanation before we proceed to base the elusive phenomena of absolute pitch upon a universal quality inherent in tones which enables us to assign them to their appropriate places in the musical scale. All things considered, the case for the outstanding octaval regions with which the chief vowel-sounds are associated is a better one; but even here there are other possibilities of interpreting the phenomena, like the one suggested

by Watt,[1] in accordance with which the vocal apparatus is assumed to find the utterance of sound at one region of pitch easier than at another; hence the tendency to give prominence to vocalization at this region and likewise at other regions, above and below, which are in octaval relationship with it.

For our present purposes we shall ignore the conflicting claims as to the qualitative aspects of tone other than the features of pitch-brightness, volume, intensity and duration which have already been mentioned, and shall confine ourselves to the first three of these in the graphic representation which accompanies this paper.

We have before us, then, a representation of the psychological aspects, or attributes, of a series of pure tones in a progressive manifold extending throughout the range of audibility. It should be noted that the dimensions of our graph are measured in terms of *psychological* and not in terms of physical components, and though we may refer to vibrational frequency and vibrational amplitude, these are to be understood as the conditions under which the psychological entities of our manifold are controlled and produced; and not as being themselves involved in the scheme.

The particular tones we have chosen to represent are the successive octaves conditioned by vibrations ranging from 16 to 32,768 per second. Each tone is pictured with a certain spread on the base-line to suggest its volume; thence rising to a peak which indicates its pitch. The height of this peak above the base-line measures *inherent intensity*, and denotes the relative sensitivity of hearing at different degrees of vibrational frequency. Duration, since it involves movement, is not included in the scheme.

It will be observed that the total spread or volume of the lowest audible tone comprises within its range the volumic emplacement of all higher tones, the extreme upper point of emplacement being identical for all tones. This accords with Watt's theory[2] and seems to be justified on the grounds he has advanced. But Watt's further assumption, that 'when

[1] *Cf. Brit. J. Psychol.*, 1914, 7, pp. 12–13.

[2] 'The Psychology of Sound,' 1917.

octaves are played, the upper tone coincides with the upper half of the lower tone . . .,'[1] is no longer acceptable in the light of Rich's determination of the threshold for volume.[2] If the increments of vibrational frequency necessary to produce liminal differences of volume depend upon a constant fractional increase in the middle range of the scale, then octaves within this range must differ by a constant number of steps, which precludes the possibility of Watt's assumption that the volume of the upper tone of an octave should always be half the size of the lower tone.

Decrease in the spread or size of volume by a constant amount is indicated for octaves throughout the musical range of the tones here pictured (64 to 2,048 vibrations). Both above and below this range, however, the fractional increase is presumed to vary. The volumes of the lowest tones are represented to be greater than the normal increase would warrant, and their pitches are displaced to the right, indicating the known tendency of low tones to appear higher in pitch than they should. Similarly the highest tones are shown decreasing more rapidly in volume than they do at the middle range; while their peaks are displaced to the left—indicating the tendency to regard tones of the four-accented octave and above as flat. The total range of volume has been divided somewhat arbitrarily into 228 steps, each step representing a discernible interval as determined by a clearly defined difference of volume. According to the investigations of Rich,[3] the threshold of volume is approximately .02 to .03 of the vibrational frequency. Since the interval of the semitone is about .06, we have taken .03, or the quarter-tone, as being the threshold for interval-distance, and have plotted the curves with abscissæ measuring 228 just noticeable differences of interval from the lowest to the highest tones.

In the middle range of the scale the volume for each octave is so plotted that it diminishes at the constant rate of 24 quarter-tone intervals. In the highest and lowest ranges of

[1] *Op. cit.*, p. 212.
[2] *Amer. J. of Psychol.*, 1919, **30**, pp. 122 ff.
[3] *L.c.* and *J. of Exper. Psychol.*, 1916, **1**, pp. 13 ff.

the scale, however, judgment of intervals is known to be less certain. Tones below 40 vibrations appear to be a little higher than would be warranted by the rate of vibration; while in the upper range tones of 3,000 vibrations and above seem flat, and at about 4,000 vibrations, according to von Maltzew,[1] accurate judgment of intervals breaks down completely. Equal decrease of volume as a basic feature in the determination of octaves and other musical intervals extends, therefore, only through tones that range from about 50 to about 3,200 vibrations in the second. The volumes of the lower tones are made relatively larger, and of the higher tones, relatively smaller, than the normal variation of the middle register would allow.

Turning now to the pitch of tones, this is indicated by the central point or salient in the upward-rising mass of volume. It will be noted at once that as volume decreases the pitch becomes more salient, or pointed. This suggests the brightness characteristic. As pitch rises it emerges more and more clearly; it becomes more and more salient. The upward trend from the base-line also suggests the variation of inherent intensity attaching to tones of different pitch-levels. The curve which circumscribes the salient peaks of these progressive tones is the one determined by Max Wien in his study of auditory sensitivity for tones of different pitch.[2] According to Wien's investigation sensitivity to tones increases rapidly from the lowest audible tones to those of about 2,000 vibrations when it begins to diminish, first slowly, and then more rapidly.

This curve of sensitivity is of especial interest because of the indication it gives as to differential sensitivity for pitch. In the lower range, successive tones coincide to so large an extent that the sensitivity for pitch is not much greater than the sensitivity for volumic differences. The pitch-salients of low tones are vague and indefinite, and an appreciable distance or interval is therefore requisite before one pitch can emerge distinctly from another. At a higher level this is not the

[1] *Zsch. f. Psychol.*, 1913, **64**, pp. 161 ff.

[2] *Cf. Pflüger's Archiv.*, 1903, **97**, pp. 1 ff.

case, for with salient tones one pitch distinguishes itself from another even though there is no perceptible volumic difference upon which a judgment of interval can rest. Thus the number of discriminable pitches within an octave increases steadily until we reach tones in the region of 2,000 vibrations when it begins to decrease. Decrease of sensitivity in the upper range, together with inability to judge volume accurately, both correlate with a falling off in ability to discriminate pitch; although the absolute difference of vibrational frequencies required for a given interval being progressively greater in the higher range, may therefore occasion a larger number of discriminable pitches per interval than is to be found for the same interval at a lower level of the scale.

We have thus represented in our figure the progression of tones throughout the range of audibility and have indicated in a general way the course taken by volume, pitch, and intensity. It remains to add a few words regarding *brightness*. In a previous paper on the attributes of sound,[1] I have suggested that brightness be added to the list of auditory attributes. It is obvious enough that sounds are characterized not only as big or little, loud or soft, long or short, high or low, but also as *piercing* or *dull*. But it is still an open question whether this latter characteristic, variously referred to as *brightness-dullness; shrillness-mellowness* and sometimes as *vocality*, merits consideration as an independent variable. Rich, who made some study of brightness in his recent experimental investigation upon the attributes of tone, comes to the tentative conclusion that while the term is valid for descriptive purposes, brightness is not independent of pitch, since each appears to have the same threshold for differential judgments. He therefore suggests that *pitch-brightness* would be a more appropriate description for a single attribute hitherto called pitch.[2] This is very probably the case as regards the tonal manifold, but as mentioned above brightness has also been linked with vocality, and it is in this connection that I still desire to recommend further investigation before

[1] *Cf.* Psychol. Rev., 1918, 25, pp. 227 ff.
[2] *Cf. Amer. J. of Psychol.*, 1919, 30, p. 157 f.

we discard it as unnecessary to the complete description of sound.

Thus far in this paper we have confined ourselves to but one species of sound—namely, tone. But there are at least two other perceptual objects of sound: the *vocable* and the *noise*. The latter may perhaps be dismissed from our present reckoning, for noise is commonly regarded as a complex sound all of whose components can be described either as tones or as vowels. Although such a conclusion is by no means certain, an additional attribute which may furnish a basis for the perception of noise is not at present under consideration.

In the case of vocalic sounds, however, we have a type of percept which offers some interesting features when it is compared with the perception of tones. The investigations of Köhler,[1] Miller,[2] and Schole[3] have indicated the regions of vibrational frequency which seem to characterize the chief vowels. Yet Köhler's conclusion that the vowel is defined by a certain pitch has not been confirmed by other investigators. Jaensch,[4] has made an apparently successful attempt to produce vocalic sounds synthetically. His results indicate that a compound of pendular-formed vibrations, varying but slightly from one another in frequency, possesses a vocalic character which passes over into noise as the mean variation of the vibrational components increases beyond a certain point. Unfortunately Jaensch's method does not permit us to determine just what vibrational frequencies combine to give an optimal vocalic effect, and as the investigation has not been repeated, his results have thus far received less attention than they seem to merit.

It is highly desirable that this matter should be re-investigated, for if it be true that the characteristic feature of a vocalic sound is obtained by compound regional vibrations, rather than by a simple pendular-formed wave, the difference between vocalic sounds and tones might be manifest when a

[1] *Cf. Zsch. f. Psychol.*, 1910, **58**, pp. 59 ff.
[2] *Cf.* 'The Science of Musical Sounds,' New York, 1916.
[3] *Cf. Arch. f. d. ges. Psychol.*, 1918, **38**, pp. 38 ff.
[4] *Cf. Zsch. f. Sinnesphysiol.*, 1913, **47**, pp. 219 ff.

variation in brightness takes place without an alteration of pitch. An investigation of Baley[1] demonstrates that the pitch of such a combination is indeed that of its mean tone, and if the components of the sound-mass are very near one another in frequency, it would certainly be impossible to analyze them perceptually. Hence the sound must be of elemental simplicity. The question is, does it possess the vocal character which Jaensch has assigned to it? If so, this change must be occasioned by an attribute other than pitch, intensity, volume, or duration. Such a variant is indicated by the term brightness, represented in our graphic scheme by the pointedness or salience of pitch; for salience must be reduced when a number of different tonal components of slightly varying frequencies are combined. While the pitch does not vary, brightness must necessarily decrease and pass into dullness; thus the characteristic of the vocalic sound is presumed to appear.

I have myself been unable to make but a casual observation with the aid of an Appunn tonometer upon the effect of compounding tones of slightly varying pitch. If one adds successive tones of slightly varying pitch on this instrument the sound becomes rapidly confused and noisy, though the tonal character of the whole does not readily disappear. But there is also noticeable a nasal quality which seemed to be most clearly manifest after the addition of a single tone. The nasal quality impressed me as vocalic and since the smallest increment on the tonometer was four vibrations, I suspect that the threshold for vocalic sounds would lie within this range of vibrational difference; though possibly the number of components necessary to reduce the saliency of pitch is more important than the range of the components.

Until further investigations have been made the whole matter is merely one of conjecture. But Jaensch's experiments are certainly suggestive, and I find nothing in the results of Köhler, Schole, or Miller to discredit them. Hence I conclude that even if brightness and pitch correlate directly with increase of vibrational frequency in the upward trend

[1] *Zsch. f. Psychol.*, 1913, **67**, pp. 261 ff.

of simple tones, brightness may nevertheless manifest a variability independent of pitch if the conditions of sound-production are such that a varied number of closely graded vibrational components unite to produce a series of sounds; for under these conditions a series is conceivable which would pass gradually from tone through vowel to noise without a noticeable change of pitch or intensity; and, at least so far as concerns the appearance of the vowel sound, without an alteration of volume.

As the sounds become noisy, we would be dealing with

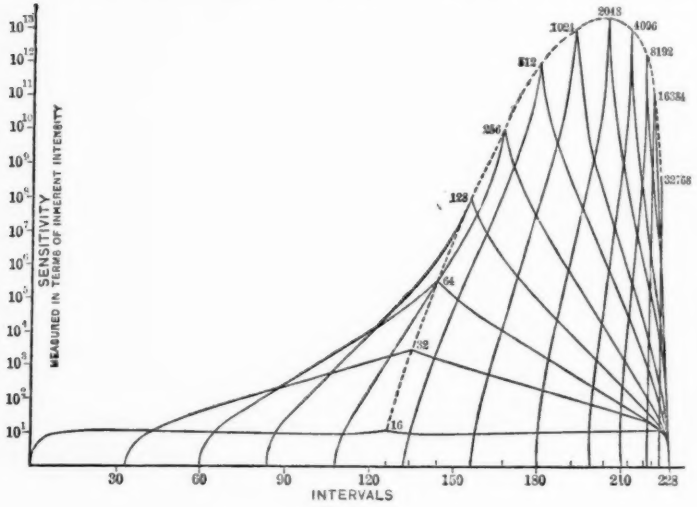

FIG. 1

components which no longer hold together in a single uniform impression, after discriminable pitch, intensity and volumic differences had one or all made themselves felt. In this connection the variation of inherent intensity with difference of pitch is also worth noting, for excepting the region of 2,000 vibrations and thereabouts, one cannot alter vibrational frequencies very much without introducing a noticeable difference of intensity which would tend to destroy the uniformity of effect even if the objective conditions of vibrational amplitude were to remain fairly constant.

Addendum

Since the preceding article was submitted for publication an opportunity has been afforded me to discuss the physical aspect of Jaensch's theory with Professor Dayton C. Miller. Although he had not read Jaensch's papers on the subject, Professor Miller finds no evidence for the "mixed sine curves" of Jaensch in his physical analysis of the vowels. But although he accepts the Helmholtz hypothesis, rather than Hermann's formant theory, his analyses show that the characteristic of a vowel is a *fixed* region of resonance, within which region must appear some partial of the fundamental tone upon which the vowel is uttered. Lacking an appropriate partial the vowel is not given. Furthermore the region of resonance in each case extends over a considerable range of pitch and the physical aspect of the significant partial is not that of a sharply defined tone, but rather that of a distribution of energy in which the amplitude of the partial in question is limited by the form in which the energy is distributed over the fixed region of resonance. Thus, if the partial falls near the middle of the resonating region of a certain vowel, its utterance is more pronounced than if it falls near the extremes of the region. But in any case the adjacent parts of the tonal region are also involved, since the distribution of a fairly constant amount of energy over the entire region is requisite to produce the vowel.

Miller's results are therefore not entirely at variance with Hermann's theory of the formant or fixed tone, which Jaensch also accepts; although Miller regards the production of the formant as a phenomenon of sympathetic resonance, while Hermann refers it to an independent "anaperiodic" blowing of the mouth resonator.

As regards the point at issue, whether the vowel is differentiated from tone by an attributive variation, Miller's analysis seems to show that not one but a number of auditory receptors are involved in its production. This is likewise the view of Jaensch. Whether the "mixed sine curves" are products of the sound wave or functions of the ear mechanism

is of secondary importance if the mode of stimulation is in either case such that what we hear is a mixture of adjacent pitches. If, as Miller agrees, a "sharp" tone in the characteristic region of resonance would tend to destroy the vowel effect, then a *dull* tone aroused by stimulating a region of resonance rather than a single resonator is the phenomenal basis of the vocalic sound. Our tentative assumption that brightness may vary independently of pitch is therefore feasible, and the way is open to determine the threshold of this variation by devising experimental means for securing a regularly graded transition from the simple, sharply defined resonance of a single vibrational frequency to the regional resonance involving a more extended series of receptors. The experimental problem is perhaps none too simple, for the variations may involve shifting amplitudes and differences of phase rather than a direct attack upon several receptors at once. In a brief paper presented before the Sixth German Congress for Psychology,[1] Jaensch suggests that the synthetic effects which occasion vocalic sounds are a result of successive waves which introduce complications of amplitude not subject to the Fourier analysis; yet the brevity of his report leaves me uncertain that I clearly understand what he means. However, despite all technical difficulties in the control of the experimental conditions, empirical methods would probably yield a means of demonstrating whether or not brightness and dullness can be varied without a corresponding alteration of pitch; and we must await such an experiment before we can be assured that brightness and pitch are separable aspects of sound.

[1] Cf. *Bericht.* Leipzig: Barth, 1914, pp. 79 ff.

IS LACK OF INTELLIGENCE THE CHIEF CAUSE OF DELINQUENCY?

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A great deal of controversy has raged about the question of the relative importance of intelligence (or the lack thereof) as a causal factor of delinquency. In the present paper I wish to discuss the bearing which actual modern statistical findings have upon this issue, in order to clear up a certain amount of confusion and misconception which seems to me to exist. Of course, in the last analysis, the answer arrived at through statistical or other methods comes back logically to the definitions of intelligence and delinquency explicitly or implicitly used by some particular author. But, to some minds, the fact that the statistician deals as a rule with objective fact, and uses methods which, as methods, are logically beyond criticism, means that the findings arrived at are also beyond cavil. It seems worth while therefore to point out that the very opposite is true. Statistical findings need not only all of the scrutiny and criticism so lavishly given to conclusions arrived at by less objective methods, but in addition there is need of the careful checking of the conclusions so far as they are interpretations of the statistical constants.

As a case in point let us take the statistical findings of Goring.[1] Goring found a correlation of +0.66 between criminality and mental deficiency, and this coefficient is considerably higher than any he found to exist between criminality and any of the other factors which he investigated. He sums up as follows: "Our final conclusion is that English Criminals are selected by a physical condition, and a mental constitution which are independent of each other—that the one significant physical association with criminality is a generally defective physique; and that the one vital mental

[1] 'The English Convict.'

constitutional factor in the etiology of crime is defective intelligence."[1] ". . . our interim conclusion is that, relatively to its origin in the constitution of the malefactor, and *especially in his mentally defective constitution*,[2] crime in this country is only to a trifling extent (if to any) the product of social inequality, or of adverse environment, or of other manifestations of what may be comprehensively termed 'the force of circumstances.'"[3] While the second conclusion is stated tentatively, Goring makes it plain that he believes that it should be accepted in the absence of contrary evidence based on better data. His position seems to me to be well stated by Miner[4] as follows: "While there is always a possibility of finding some other factor closely related to delinquency and independent of capacity, nevertheless we should hardly urge this possibility at the present time as overweighing the accumulation of negative evidence which has been assembled in recent years, especially at the Galton Laboratory."

In other words, Goring guards himself sufficiently against the possibility that further research *may* reverse his findings through the discovery of new and better evidence. He does not seem to see that the future *must* reverse his conclusions, or, better, that his conclusions simply do not follow from his statistics. He is correct when he states that the Intelligence-Delinquency relation is the most important relation measured so far statistically. He is absolutely wrong when he claims that, in the absence of other data, we must accept his conclusions as the nearest approach to the truth attained thus far. For if the coefficient of the correlation between intelligence and delinquency is + 0.66, the correct conclusion to be drawn is that it is exceedingly probable that factors other than intelligence are of *greater* importance as determinants of crime than intelligence.

This conclusion follows from the following considerations. If we have a number of variables one of which is of special interest, it is possible to express the relation of these variables

[1] 'The English Convict,' p. 263.
[2] Italics mine.
[3] *Ibid.*, p. 287.
[4] 'Deficiency and Delinquency,' p. 228.

in a single equation. Let D stand for delinquency, I for intelligence, and N for a combination of all factors other than intelligence. The equation will then take the form[1]

$$d = i\left[r_{di \cdot n}\frac{\sigma_{d \cdot in}}{\sigma_{i \cdot dn}}\right] + n\left[r_{dn \cdot i}\frac{\sigma_{d \cdot in}}{\sigma_{n \cdot di}}\right]$$

In order to understand the meaning of this equation a certain amount of explanation will be necessary for the reader not versed in this form of mathematics. The explanation however has been confined to the minimum which is absolutely necessary, and, if the reader will take the mathematical assertions for granted, he will be able to follow the argument of the rest of this paper. The expressions in brackets are the coefficients of partial regression. They are, in effect, the measures of the relative importance of intelligence and of the other factors. For the sake of simplicity of statement let us assume that the sum of the factors other than intelligence can be summed up under the term *economic status*. Then if the measure of the intelligence of any given individual is known, and if that measure is multiplied by the coefficient of partial regression of intelligence on delinquency, the result will be the measure of the delinquency of that individual which one would expect from his intelligence, independent of his economic status; and if the measure of the economic status of that individual is multiplied by the coefficient of partial regression of economic status on delinquency, the result will be the measure of the delinquency of that individual which one would expect from his economic status, independent of his intelligence. The sum of the two terms will be the total expected delinquency of the individual.

The expression $r_{di \cdot n}$ is the coefficient of partial correlation of intelligence and delinquency. It measures the correlation of delinquency to intelligence, independent of economic status. If, for example, the entire population were arranged into classes according to economic status, so that all individuals within any one group were equal in wealth to all other members of their group, then, within any such group,

[1] In this equation, D, I, and N are expressed as deviations from their respective means in terms of their respective standard deviations.

differences in delinquency cannot possibly be related to differences in economic status, because, within any such group, there are no differences in economic status. Therefore, within any such group, the correlation of intelligence to delinquency is independent of economic status. Similarly, the coefficient of correlation $r_{dn \cdot i}$ is the measure of the correlation of economic status to delinquency, independent of intelligence.

The reader should be careful not to confuse coefficients of correlation with coefficients of regression. The one is a measure of relation; the other is a measure of relative importance. Consider for example the effect of the moon, the sun, and the planet Jupiter upon the height of the tides. If we were able to measure with absolute accuracy the influence of each of these heavenly bodies, the partial correlation between the position of Jupiter and the height of the tides would be well nigh perfect, but the relative importance of the position of this planet would be negligible.

Having explained the meaning of the terms of our equation, we may return to the consideration of the equation itself. In any given actual case, the right and left sides of this equation will not be exactly equal. For example, if we estimate the degree of delinquency of any given individual from his known intelligence and from the other known causes, the estimated delinquency will be likely to differ from the actual delinquency because we are dealing with imperfect measures of intelligence, environmental influence, etc., and because we are sure to have left some of the causal factors out of account. If however we imagine ideally perfect conditions—if all the causes of delinquency were known and accurately measured—the two sides of the equation would be exactly equal. Further, both $r_{dn \cdot i}$ (the coefficient of the relation of delinquency to factors other than intelligence, intelligence being constant) and $r_{di \cdot n}$ (the coefficient of the relation of delinquency to intelligence, all other factors being equal) would be equal to unity, because, under the ideal conditions imagined, the degree of intelligence would of course be a perfect measure of delinquency, so far as caused by lack of intelligence, and "all

other factors" would measure perfectly "all other resultant delinquency."

The above considerations open up the possibility of subjecting Goring's conclusions to *quantitative* criticism. For the present I would direct the attention of the reader to the following quantitative problem. Given a correlation of + 0.66 between lack of intelligence and delinquency, under what circumstances will the correlation to delinquency of a combination of all other causal factors be greater than + 0.66?

TABLE I

1 $DN \cdot I$	2 $DI \cdot N$	3 DI	4 IN	5 DN
1.00	1.00	0.66	−0.20	0.604
1.00	1.00	0.66	−0.14	0.652
1.00	1.00	0.66	−0.13	0.659
1.00	1.00	0.66	−0.12	0.667
1.00	1.00	0.66	0.00	0.751
1.00	1.00	0.66	0.20	0.868
1.00	1.00	0.66	0.40	0.953
1.00	1.00	0.66	0.60	0.997
1.00	0.66	0.66	0.66	1.000

Table I. supplies the answer to the problem. Column I. shows the coefficients of partial correlation between delinquency and the factors other than intelligence, intelligence being constant. The coefficients are 1.00 in every case under the assumed ideal conditions. Column 2 shows the coefficients of partial correlation of delinquency to intelligence, all other factors being constant. These coefficients are 1.00 in every case except in the special case where r_{dn} is 1.00, when $r_{di \cdot n}$ will take the value of + 0.66 for reasons which will be easily understood. Column 3 shows the coefficients of correlation of delinquency to lack of intelligence, which are + 0.66 in every case by definition. In column 4 there are a number of assumed coefficients showing a number of possible values of the correlation of lack of intelligence to all other factors. Column 5 shows the coefficients of correlation between delinquency and all factors other than intelligence which would *necessarily* result from the conditions assumed in the other 4 columns. Thus, taking the first horizontal

line, if the coefficient of correlation of lack of intelligence to delinquency is + 0.66, if the coefficient of correlation of intelligence to the other factors − 0.20, and if the analysis is ideally complete as indicated by the coefficients of partial correlation of columns 1 and 2, then the coefficient of correlation of the factors other than intelligence to delinquency will necessarily have a value of + 0.604.[1] And from the rest of the table we see that it will have a value equal to or greater than + 0.66 if the coefficient of the correlation of lack of intelligence to the other factors is between − 0.13 and + 0.66.

Common sense would indicate (in a situation involving only 3 variables), that the above also shows the limits within which the factors other than intelligence are of greater importance than intelligence. But as a quantitative statement of the coefficients of importance (regression) may be of some interest, I have tabulated them in table II, which is merely an extension of table I with the first three columns omitted. The reader will remember that the coefficient of correlation of intelligence to delinquency is 0.66 in every case.

TABLE II

4 Correlation *IN*	5 Correlation *DN*	6 Regression *DI · N*	7 Regression *DN · I*
−0.20	0.604	0.8134	0.7667
−0.14	0.652	0.7658	0.7587
−0.13	0.659	0.7586	0.7577
−0.12	0.667	0.7505	0.7567
0.00	0.751	0.6603	0.7513
0.20	0.868	0.5068	0.7667
0.40	0.953	0.3306	0.8197
0.60	0.997	0.0968	0.9391
0.66	1.000	0.0000	1.0000

Columns 4 and 5 are identical with columns 4 and 5 of Table I. Column 6 shows the coefficients of partial regression of intelligence on delinquency, all other factors being constant, and column 7 exhibits the coefficients of partial regression of

[1] The coefficients of column 5 were computed by solving the conventional equation for a coefficient of partial correlation for r_{dn}. For this formula as well as the other formulæ utilized in this paper, see Yule's 'An Introduction to the Theory of Statistics,' Chap. XII.

the factors other than intelligence on delinquencey, intelligence being constant. Thus under the conditions of the first horizontal line of Tables I. and II., the importance of intelligence is to the importance of the other factors as $+0.8134$ is to $+0.7667$. We see that "the other factors" begin to be of more importance than intelligence when their correlation with intelligence is -0.12, and, as this last relation becomes positive and increases in value, the other factors become twice, and even ten times as important as intelligence. Although I do not mean to enter into the psychological aspects of the case in the present paper, I may remark in passing that these figures become highly suggestive if one believes that *character* is closely related to *intellect* without being in any sense identical with it.

At any rate, it follows from these figures that lack of intelligence is *not* the most important factor in the causation of delinquency *unless we have a right to assume that the coefficient of correlation of intellignece to the other factors is negative and greater than* -0.12. But according to the best of our present knowledge, the very opposite is very probably true. We may divide the causal factors of delinquency other than lack of intelligence into environmental factors and factors peculiar to the individual. So far as the environment is concerned, we know that poverty, absence of parental care and supervision, and other evils in and out of the home predominate amongst the ignorant. Indeed it is often urged by those who wish to minimize the importance of the environment that the poor are stupid not because they are poor, but that they are poor because they are stupid. For our present purpose, we are not concerned with this issue except to note that ignorance and poverty and other environmental factors go together and cannot therefore be negatively correlated. Therefore, so far as we have gone, we have no reason for believing that Goring has shown that lack of intelligence is the most important factor in the causation of delinquency. Our evidence, so far, points in the opposite direction. So far as the factors peculiar to the individual are concerned nothing very definite can be said in the present state of our knowledge.

Definitions in this field are either lacking or are so vague and general that they tend to confuse rather than clarify issues such as the one we are considering. Intelligence, for example, is usually defined as the ability to adapt to the environment, and, inasmuch as anything which makes for detected delinquency necessarily makes for maladaptation, other factors would be ruled out by definition. It is however worthy of note that many authors hold to the existence of factors other than intelligence and therefore depart from the all comprehensive definition of intelligence, implicitly at any rate. Obviously then it is impossible to say anything very definite about the probable sign of the correlation existing between intelligence and other causes of delinquency. In the near future the writer hopes to show that intelligence and moral character, when subjected to functional psychological analysis, have many factors in common, so that there is every reason for believing the relation between them to be positive. At present it must suffice to point out that there is no reason for believing it to be negative. And, as there is good ground for believing that the relation of intelligence to the environmental factors is positive, there would seem to be good grounds for holding that lack of intelligence is not the most important cause of delinquency, and no grounds at all for holding that it is.

But even though lack of intelligence is not of greater importance than all other factors taken in the aggregate, it may be urged that a correlation of + 0.66 shows that it is likely to be the largest *single* factor. The following hypothetical example will show that that is not at all likely to be the case. Suppose that in addition to lack of intelligence there are six other known causes of delinquency, X_1, X_2, X_3, X_4, X_5, and X_6, or seven causes altogether. Let the correlation of each of these seven causes to delinquency be + 0.66, and let all the possible intercorrelations of the seven causes with each other be + 0.50. Let the relation of delinquency to these seven causes be expressed in a single equation, as on page 149. Then suppose that the degree of delinquency and the intensity of the seven causes under consideration is

known with perfect accuracy for a very large number of individuals and that, for each individual, these values are entered into the equation. Then, if our seven causes have furnished us with a complete analysis of the causes of delinquency, the right and left sides of the equation will be exactly equal in each and every individual case. If the analysis is incomplete, that is if there are causes not included under our seven, there will be differences between the actual and the estimated degrees of delinquency. Now if the coefficient of the correlation existing between the actual and the estimated values be determined, we have in that coefficient a measure of the closeness of our approach to completeness of analysis. We shall designate this special coefficient by the symbol *R*. If the analysis is complete, *R* will be equal to one. Otherwise it will be less than one and the amount by which it falls short will indicate the importance of the causes left out of account.

Now in our hypothetical example *R* is equal to + 0.873. In other words, our analysis is incomplete even though we have taken into account six other causes of delinquency as highly correlated with delinquency as Goring found lack of intelligence to be. An idea of the incompleteness of the analysis may be gained from the fact that the average difference between the actual and the estimated delinquency would be half of what this difference would be if *R* were zero.[1] Indeed, if I had not shunned the labor of computation, I could easily have taken twenty causes related to delinquency as highly as our seven and still have reached an *R* unmistak-

[1] *R* would be zero only if the coefficients of correlation to delinquency of each of our seven "causes" were zero. In that case they would, of course, not be causes at all. Nevertheless our regression equation would still yield the most reasonable estimate possible in the circumstances of the degree of delinquency of any given individual. Having no knowledge at all of the causes likely to produce delinquency, it would be most reasonable to estimate the degree thereof as the average degree. For example, if one were to estimate the height of John Doe, John Doe being any individual whatever about whom nothing at all is known except that he lives in Chicago, it would be most reasonable to take his probable height to be the average height of the male citizens of Chicago. Now if we were to estimate the degree of delinquency of each and every individual by means of the regression equation based upon our seven assumed causes, our average error would be half as great as if we were to estimate that degree of delinquency to be the average degree of delinquency of the entire population.

ably below one. The truth of this last statement can be strongly suggested by showing how much each additional cause adds to the value of R in our hypothetical example. I have done so in Table III.

TABLE III

$R_{d(i)}$	= 0.660
$R_{d(ix_1)}$	= 0.762
$R_{d(ix_1x_2)}$	= 0.808
$R_{d(ix_1x_2x_3)}$	= 0.835
$R_{d(ix_1x_2x_3x_4)}$	= 0.852
$R_{d(ix_1x_2x_3x_4x_5)}$	= 0.864
$R_{d(ix_1x_2x_3x_4x_5x_6)}$	= 0.873

The first R is computed on the basis of one cause only; the second on the basis of two; the third on the basis of three, etc. It will be seen that R increases rapidly at first and then more and more slowly. It seems that a great many more causes would be needed to reach a value of one, if indeed it can be reached at all, for R may be approaching a limit of less than one. That is, if causes are intercorrelated to the degree which we have assumed in our hypothetical example, it may be impossible to reach completeness of analysis even with an infinity of causal factors.[1]

It would be possible to keep ringing the changes on the various hypothetical combinations of causal factors which might be formed. I trust what has been done will be enough to validate our claims. Summing up, they are:

1. The claim that Goring's statistics *prove* lack of intelligence to be the chief cause of delinquency, at any rate until better data are at hand, is due to a mistaken interpretation of his statistical results.

2. His results *do* show that very probably lack of intelligence is of *less* importance than all other factors combined.

3. They show, also, that lack of intelligence is probably of less importance than one or more other factors, taken singly.

In conclusion I wish to say that, in the present paper, terms such as intelligence, delinquency, etc., are used un-

[1] *Cf.* Pearson, *Biometrika*, Vol. 10, p. 181.

critically and naïvely. Whatever definitions of these terms may be implicit in Goring's data are accepted by me without question. For the present paper addresses itself only indirectly to the larger problem of the *real* significance of the causal factors of delinquency, and is concerned mainly with the correct interpretation of statistics. In the near future I hope to be able to publish some views on the more important *psychological* analysis of the factors which are summed up under such headings as intelligence and character, so far as they are causes of delinquency.